Exploring responsible innovation of large technological systems in society

Ortt, Roland; van de Poel, Ibo; van Putten, David; Kamp, Linda

Publication date
2020

Document Version
Final published version

Published in
Responsible Innovation in Large Technological Systems

Citation (APA)
Ortt, R., van de Poel, I., van Putten, D., & Kamp, L. (2020). Exploring responsible innovation of large technological systems in society. In J. R. Ortt, D. van Putten, L. M. Kamp, & I. van de Poel (Eds.), *Responsible Innovation in Large Technological Systems* (1 ed.). Routledge - Taylor & Francis Group. https://www.taylorfrancis.com/books/e/9781003019930/chapters/10.4324/9781003019930-1

1 Exploring responsible innovation of large technological systems in society

J. Roland Ortt, Ibo van de Poel, David van Putten and Linda M. Kamp

1.1 Introduction

1.1.1 Societal relevance of responsible innovation

Technological innovation is important. From a societal perspective, technological innovation is seen as a virtue. It has enabled the creation of products and systems that have facilitated our lives and have made our daily life more comfortable, safe and healthy. Moreover, technological innovation has allowed us to become wealthier, to travel world-wide and to communicate with people across the globe. However, technological innovation is also accompanied by severe accidents, pollution and a painful division between the haves and have-nots (Florman, 2000; Perrow, 2011). The steam engine, for example, although invented in the 18th century, was a central system in the industrialisation era that started to change our society fundamentally from the mid-19th century on. At that time, during the 1840s, Marx was in London writing his book on the exploitation of the working class in the new industrialised society that emerged with the application of the steam engine. At the same time, just a few blocks away in the same city of London, the first World Exhibition was devoted to presenting the virtues of technological innovation (Nasar, 2011). Both perspectives, the steam engine as a virtue and as a curse, seem valid in hindsight. Many casualties were caused by steam engines that exploded. We learned in a kind of trial-and-error process to deal with the enormous pressures that steam engine vessels have to withstand. The industrial revolution around the Thames in London may have been the beginning of our wealth, yet the working class was living in deplorable neighbourhoods full of filth, poverty and diseases. This became such an enormous problem that economists devoted their work to solving this problem: how to deal with the furious competition that forced wages down to the level where workers could barely survive. At the same time, owners of the companies that benefitted from cheap labour and machines such as the steam engine became richer and richer. Marx was addressing a serious problem, and so were Malthus, Smith and many icons of economics and sociology (Nasar, 2011). Opposing views regarding the virtue (or curse) of societal changes that accompany technological innovation can be found for other technologies as well,

such as communication technologies (Rogers, 1986; Short, Williams and Christie, 1976), nuclear power technology (Peters and Slovic, 1996) and many more.

1.1.2 Exploration of the concept of responsible innovation

From the era of industrialisation on, when technological innovation started to fundamentally change our society, responsibility became an issue. Several issues come to the fore when responsibility of innovation is explored.

Firstly, responsibility for whom? Responsible innovation means that different groups of stakeholders and their (sub)cultures are respected in the process of developing, implementing, operating and discarding innovations, including future generations. This also means that technological innovation should be sustainable. Technological innovation has created the Chernobyl and Fukushima accidents, the resulting nuclear contamination of which will be felt for centuries. Technological innovation has also created the energy that we need for living comfortably. Technological innovation has polluted the world, significantly increased the average temperature, changed the climate and thereby caused natural disasters, wars and mass migration. Technological innovation has also enabled us to connect to and travel to people across the world. The issue of *who* should be considered during responsible innovation will be addressed in several practical cases in this book.

Secondly, when should responsibility be considered? Responsibility is important during the first innovation project in which a new technological system is created but it is also important during the ongoing process of improvement and growth of such systems during their whole lifetime. Responsibility is even important in the way in which the technological systems are discarded after becoming obsolete. Both perspectives on the timeframe when responsibility should be considered will be described in this book.

Thirdly, responsibility for what? What are the aspects that should be considered when we assess the responsibility of a technological innovation? Responsibility refers to a range of aspects: privacy of individuals, security, respect, a fair division of wealth, sustainability, and so on. Some of these aspects conflict with each other: maximum security against terrorism, for example, can only be created at the expense of privacy. Increase in wealth has created pollution. Apparently responsibility is about values (privacy, security, sustainability, wealth, …) and about balancing these values. The issue of which aspects should be considered during responsible innovation will also be addressed in this book.

Values change over time. In the present, we may choose, for example, to value information above all. We are currently in the process of developing bigger and better technologies for storing, transferring and analysing data. The benefits of this wealth of information are evident. Everything from traffic management to marketing and taxation is becoming more efficient. Processes are automated and money is being saved. Yet at the same time, there are other values besides efficiency that perhaps remain neglected. The privacy of individuals, the justice of the decisions made by algorithms or the fairness of the transactions of our information may not always be accounted for. Data science thus risks being a

decidedly one-sided innovation, which emphasises the values of stockholders over those of stakeholders, with a potentially morally problematic situation as a result. Responsible innovation, on the other hand, implies that we develop a mode of innovation that includes consideration for these other values – indeed perhaps a way of innovating that includes as many of these considerations as possible. The future of technology and whether or not it will be a virtue or a curse depends on the conditions under which this process of innovation takes place.

In short: this book is devoted to describing and defining responsible innovation, both as a process and as an outcome, for technological systems in society.

1.1.3 Development of responsible innovation as a research topic

Responsible innovation is a most fascinating topic. In the vast literature on innovation the concept of responsible innovation is a recent and emerging concept that has gained momentum during the last decade. Many publications are devoted to describing and defining innovation. Innovation is seen as a process and as an outcome of that process. Innovation processes are described at the level of a project within companies, for example projects that are organised and structured as a stage-gate or as an agile process (Cooper, 2008 and 2014; Cervone, 2011; Paul and Singh, 2012; Sommer et al., 2015). Innovation processes are also described at the level of an industry or even society, for example the development and diffusion of plastics in the 20th century (Dubois, 1972; Friedel, 1983). Innovation as an outcome is defined to refer to new types of organisation, production, business models, marketing mixes, products and services (Rogers, 2003). Many characterisations of these innovations in terms of their novelty, radicality or degree of disruption have appeared in the literature. Several authors have tried to give an overview of these characterisations (e.g., Garcia and Calantone, 2002; Veryzer, 1998). And yet another type of innovation has appeared: responsible innovation.

Figure 1.1 clearly shows that responsible innovation is an emerging and relatively new concept in the scientific field of innovation. The notion of responsible innovation becomes more and more developed. As we will illustrate in the next section, different definitions of responsible innovation can be found in the literature. Therefore, unification and an overarching vision of responsible innovation are required.

1.1.4 Focus of this book

This book contributes to the emerging field of responsible innovation by addressing two research questions:

- How can responsible innovation be defined?
- How to do it?

The book will focus on large societally relevant technological systems. These systems can be utilities such as gas and electricity provision, transport systems

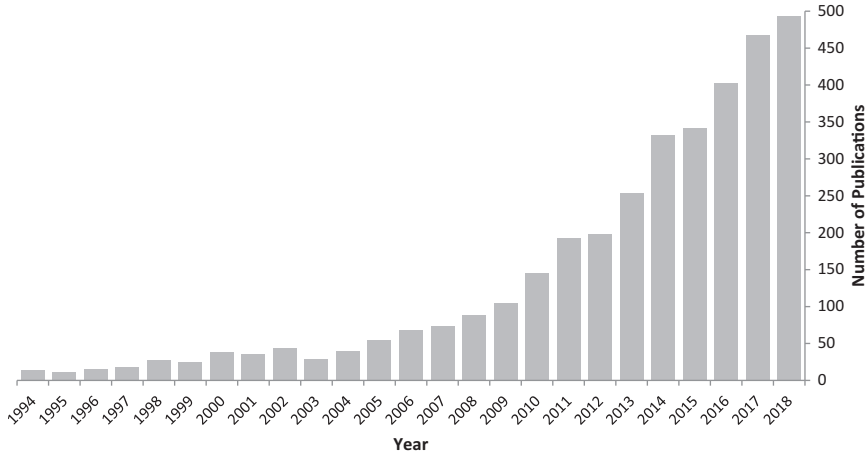

Figure 1.1 Number of articles published during the period 1994–2018 (25 years) on the topic of responsible innovation, found using Web of Science

such as the water infrastructure, and many other vital systems in our society. These systems in particular will be relevant for many different groups of stakeholders, now and in the future.

This is definitely not the first book on responsible innovation. Several of our authors contributed to earlier publications on responsible innovations during the last two decades. What is new is our specific focus on societally relevant technological systems, and the goal to combine multi-disciplinary perspectives with a deliberate focus on how to implement responsible innovation in practice.

1.1.5 Goals of this book

A first goal of the book is to illustrate how responsible innovation can be defined by discussing how it is applied or can be applied in specific cases of societally relevant large technological systems. First, in the next section of this introductory chapter, some definitions of responsible innovation as presented in the current literature will be discussed. This discussion is the first basis for the definition of responsible innovation that is developed in this book. After that, the case study descriptions in the subsequent chapters of the book all add one or more aspects to the insight into what responsible innovation can be. In the concluding chapter we will present an overarching definition based upon the contents of this book. A second goal is to show how responsible innovation can be applied in practice. What are the dilemmas, debates and issues that emerge in practice? And, secondly, what are the methods, tools and strategies to deal with them?

1.1.6 For whom is this book?

This book describes responsible innovation in terms of both the innovation process and the innovation outcome, and in doing so it focuses on historical cases of innovation in large societally relevant technological systems. The topic and focus of the book make it relevant for a variety of readers. Some of these readers benefit mainly from its scientific contribution. Masters students and scholars in the field of innovation management, ethics and related disciplines, for example, could be inspired by the diverse disciplinary perspectives on responsible innovation, the diversity of cases, the methods and tools used, and most of all, the resulting answers to the two main research questions: How can responsible innovation be defined? How to do it? Some readers benefit mainly from the practical contribution of this book. Masters students, project managers and policy makers can use the cases to find out how to make innovation processes of large societally relevant technological systems (more) responsible.

1.2 Predecessors of responsible innovation in theory and practice[1]

1.2.1 Introducing predecessors

Responsible innovation, both as a process and as an outcome, has existed much longer *in practice* than the emergence of the term and the accompanying stream of publications (as reflected in Figure 1.1) imply. In Chapter 7, for example, it is described how innovation processes and their outcomes in the field of wind power, more than a century ago, can be considered quite responsible. During the development and implementation of wind turbines around 1900 in Denmark, the outcome of the innovation process served important societal goals, while the process of development and implementation of these wind turbines actively involved relevant stakeholders. The Danish government was able to stimulate and nurture these innovation efforts. Responsible innovation will probably exist as long as humanity develops and implements new technologies.

Responsible innovation has also existed much longer *in theory* than the emergence of the term and the stream of publication imply. Because of the focus of this book, how to define and implement responsible innovation of societally relevant technological systems, we would like to describe two groups of scientific literatures that preceded the notion of responsible innovation. The first group comprises two related literatures on innovation and diffusion of 'Complex Product Systems' (CoPS) and 'Large Technological Systems' (LTS). The second group refers to the literature of 'Technology Assessment' (TA). Both groups will be introduced and we will discuss how they paved the way for responsible innovation on societally relevant technological systems.

1.2.2 Complex Product Systems and Large Technological Systems literatures

The two literatures obviously focus on the kind of systems that we focus on in our responsible innovation book. We will introduce the literatures one by one. From the descriptions of these literatures we will derive why responsible innovation is such an important perspective for these technological systems and how the nature of these systems calls for particular ways to manage their innovation processes.

Complex Product Systems

Complex Product Systems (CoPS) are large-scale, engineering intensive products that are supplied in unit or batch production and tailored to meet the requirements of particular large users (Davies and Brady, 1998). Hobday (1998) agrees on the engineering intensive aspect of CoPS, stressing two extra aspects that characterise these systems: CoPS are highly customised systems and they often require several producers to work together simultaneously. CoPS are often defined and described in contrast to mass produced commodity goods (Hobday, 1998). Examples of CoPS are cellular mobile communication systems (Davies, 1997; Davies and Brady, 1998), flight simulation (Miller et al., 1995), or the electric vehicle (Dyerson and Pilkington, 2000).

The complex system nature of Complex Product Systems (CoPS) has an impact on their innovation process and in particular on the types of stakeholders involved in this process. CoPS most often involve large users, such as large corporations or large public institutions, that are involved throughout the innovation process. Because of their societal relevance and impact CoPS also have to deal with governmental regulations and laws (Davies and Brady, 1998).

> While major differences between groups of CoPS are apparent, user involvement in innovation tends to be high and suppliers, regulators and professional bodies tend to work together with users ex-ante to negotiate new product designs, methods of production and post-delivery innovations.
>
> (Hobday, 1998, p. 689)

In short, innovation processes of CoPS are likely quite different from mass produced commodity goods (Hobday, 1998).

Large technological systems or infrastructures

Large technical systems (LTS) are the kind of complex systems that are performing vital functions in society such as transport, energy provision and communication and that are present throughout society. As a result, these systems reflect the structure of the entire society: they affect and are affected by society. Another result of the function and the presence of these systems is that these systems show many interrelationships with different types of actors in society. In the words of Gokalp (1992, p. 58):

> in society they (i.e., large technological systems) are characterised by being both global in scope and global in structure. Global in scope means that most people in most places are affected by them at least some of the time. Global in structure means that multiple factors contribute to shape the structure and dynamics of a given process or situation.

Examples of large technological systems (LTS) are electricity systems (Hughes, 1987) or transport systems (Gokalp, 1992). A specific branch of literature, referred to as 'Infrastructures' focuses on LTSs that are considered critical for the functioning of society, such as transportation, oil and gas production and storage, water supply, emergency services, government services, banking and finance, electrical power, and information and communications (Edwards, 2003).

The scope and the nature of large technological systems (LTS) and their interrelationships with other parts of society have an impact on their innovation process. Gokalp (1992) describes a generic innovation and implementation process for LTSs comprising four stages: 1) the initial phase; 2) the accelerated development phase; 3) the stabilisation phase; 4) the decline phase (Gokalp, 1992, p. 58). In the initial phase several separate and parallel activities regarding the system can be witnessed without an overall plan or coordination. This phase is characterised by intense debate about the system advantages. Experiments and pilots of the system, quite often in a hybrid combination with existing systems, can be found. In the accelerated development phase, an overall plan and coordinated system design starts to emerge. The virtues of the system are now clear and implementation starts. In the stabilisation phase the rate of implementation stabilises and a mature system is now implemented in society. In the decline phase, the system is decreasing in scale and scope. The role of relevant stakeholders is sometimes suggested to vary over the stages of the innovation and implementation process. Hughes (1994) for example illustrates, using several historical examples, that 'younger developing systems tend to be more open to sociocultural influences while older, more mature systems prove to be more independent of outside influences and therefore more deterministic in nature' (p. 101). In short, innovation processes of large technological systems are not seen as a kind of innovation project but more as the life cycle of a system in society over prolonged periods of time in which stakeholders affect the process and are affected by the process.

These two related categories of literatures, in short referred to as CoPS and LTS, seem to stress how central and engrained these technologies are in our society and hence how important a responsible innovation approach is when developing, implementing and adapting the system. Because of the large scope of these systems, such a responsible innovation approach or process involves interaction with many groups of stakeholders. The outcome of the process, the system itself, should also be responsible because of its central role in society.

1.2.3 Technology assessment literature and practice

Technology assessment emerged as a phenomenon in the early 1970s in the USA.

> Technology assessment has been defined as a form of policy research that examines short- and long-term consequences (for example, societal, economic, ethical, legal) of the application of technology. The goal of technology assessment was said to provide policy makers with information on policy alternatives.
>
> (Banta, 2009, p. 7)

The research fields of Technology Assessment (TA) and Responsible Innovation (RI) are closely related.

Technology assessment was initiated in the early 1970s in the USA. The aim was to inform politicians about a few selected technologies with potentially large implications for society, such as supersonic transport, pollution of the environment and ethics of genetic screening (Grunwald, 2009; Tran and Daim, 2008; Banta, 2009). Later on, this type of TA was called Classical TA. TA became institutionalised in the 1970s in the USA with the funding of the OTA, the Organization for Technology Assessment. Later on, similar organisations were initiated and funded by several European governments (Van Eijndhoven, 1997).

Over time the TA approach was improved and further developed. For example, a review process was implemented which involved both practitioners and scientists. Also, conferences were organised in which TA organisations, scientists and politicians together set the agenda, improved tools and methods and exchanged information on technologies. The reports of separate TA organisations on specific technologies were often shared across countries in order to prevent unnecessary duplication of work.

The TA approach was further developed into different directions at the same time. Awareness TA started to also suggest alternative policy options to deal with the consequences of new technologies. Furthermore, especially in Europe, Participatory Technology Assessment (PTA) and Constructive Technology Assessment (CTA) were developed. Participatory Technology Assessment involved including public discussions on new technologies in order to inform and involve wider groups of stakeholders, including the general public. These discussions served as an input for policy makers (Van Eijndhoven, 1997). The aim of Constructive Technology Assessment was to feed back the outcomes of TA studies to technology developers and researchers so that they could steer their innovation process into societally relevant directions, for example by considering preventing accidents or negative side effects of new technologies as an important requirement during the innovation efforts (Schot and Rip, 1997).

In 1995 funding for TA was discontinued quite abruptly in the USA by the Reagan government. A few years later, most of the European governments curtailed their investment in TA too. As a consequence, also the scientific field of TA started to decrease. Interestingly, in the same period, the research field of

responsible innovation came up. Although it had different scientific roots than Technology Assessment, there were many overlaps in terms of content. It also focused on how to steer technology development into a more responsible, desirable direction. And it also aimed at having an impact on innovation processes. However, there are also some differences. Responsible innovation has been more concerned with ethical considerations about what responsible innovation ought to look like and less with 'doing it' in practice. That is where TA was more developed – involving stakeholders and their stakes in the discussions about technological developments, and feeding back the results of these discussions to policy makers and technology developers. This last point is very interesting for this book, especially for answering the second research question: 'How to do it?'

1.3 Responsible innovation in the literature

1.3.1 Definitions and characterisations of responsible innovation

In this book we apply and further develop the responsible innovation approach. In the literature, a variety of definitions and characterisations of responsible innovation can be found. The Rome Declaration on Responsible Research and Innovation for example defines responsible innovation as 'the on-going process of aligning research and innovation to the values, needs and expectations of society' (European Union, 2014, p. 73). Another influential definition has been given by Von Schomberg, who defines responsible innovation as a 'transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products' (Von Schomberg, 2012). Responsible innovation requires attention to the *process* of innovation that should meet such criteria as being anticipatory, reflective, deliberative and responsive (Owen et al., 2013). It also requires attention to the products or *outcomes* of innovation that should meet deeply held moral values such as justice or security (Van den Hoven, 2013).

1.3.2 Seven common aspects in definitions of responsible innovations

Although different definitions of responsible innovation emphasise somewhat different aspects, the following issues are often included in the responsible innovation approach. First, responsible innovation anticipates possible uses and impacts of a technology in society and feeds these insights back to the innovation (as an outcome) and the innovation process (resulting in that outcome) (e.g. Owen et al., 2013; Stilgoe, Owen, and Macnaghten, 2013). Second, responsible innovation aims at minimising the harms and risks of a technology and maximising its social benefits (Directorate-General for Research and Innovation EU 2012, Committee to Review the National Nanotechnology Initiative National Research Council 2006). Third, it is reflective with respect to values and aims and it is aimed at integrating values of ethical importance, such as safety, sustainability, privacy, justice, democracy and responsibility, into the design and development process of new technology

(Friedman and Kahn, 2003, Van den Hoven, 2013; Van den Hoven, Vermaas, and Van de Poel, 2015). In doing so, it aims at technologies that are more morally acceptable and that are also more likely to be socially accepted (Directorate-General for Research and Innovation EU, 2012; Von Schomberg, 2012; Directorate-General for Research and Innovation EU 2013). Fourth, it aims to be inclusive and participatory by including the views of a range of different stakeholders in the innovation process (European Commission, 2012; Owen et al., 2013; Stilgoe, Owen, and Macnaghten, 2013). Fifth, it is aimed at contributing to solving grand societal challenges such as health, food, energy, transport, climate change, immigration and security (European Commission, 2012). Sixth, it is responsive to societal expectations about new technology and also responsive to changing circumstances, knowledge, and perspectives including new social and ethical issues that might arise also after a technology has been introduced into society (e.g. Stilgoe, Owen, and Macnaghten, 2013; Van de Poel, 2016). Seventh, a responsible innovation process is open, transparent to outsiders, and is organised in such a way that the choices made can be accounted for (e.g. Von Schomberg, 2012).

All these aspects can also be found in the contributions to this book, but to different degrees in the various contributions. Despite the variety of contributions, there is a common thread that is shared by the contributions. Because of the focus of the book on large societally relevant, technological systems, most contributions take a systems perspective in which social and technological aspects are explored in combination. A second common thread is that there is a lot of attention for the different stakeholders. In particular in the case of sociotechnical systems, there is often a large variety of stakeholders that is not only impacted by the technology but also has an impact on its functioning and success. A third common thread is an attention for values and how they are integrated in the design and innovation process. An aspect that in particular comes to the fore in various contributions is conflicts around values. Sometimes value conflicts are brought about by the fact that different stakeholders interpret or understand a value differently. In other cases two or more values may be conflicting in the sense that they cannot both be (optimally) taken into account simultaneously in the development of the technological system.

1.4 Methodology used in this book

Since responsible innovation is an emerging topic, both in academia and in practice, we decided to adopt a case-based approach. Limited practical knowledge about the implementation of the concept calls for the description and critical analysis of practical cases. Limited and non-consolidated scientific knowledge about the definition of the concept and the tools, methods and overall approach of responsible innovation inspired us to make an edited book rather than a monograph. The edited book allowed us to invite scholars with diverse disciplinary backgrounds. In combination, the emerging nature of responsible innovation, both in academia and in practice, made us choose a case-based and edited book with many different scholars to contrast the vision of several disciplines on the experiences with a variety of cases.

We invited several multi-disciplinary teams of authors to carefully describe the innovation process of a large technological system in society. Rather than choosing one theoretical perspective on responsible innovation, we decided to give the authors complete freedom to describe the case and use whatever theory or concept they preferred to make sense of their observations, as long as they addressed the main research questions of this book: How can responsible innovation be defined? How to do it?

Each chapter deals with a case of a large societally relevant technological system. In order to understand the context of the innovation process of these technological systems in society, we requested authors to describe the technological system, the stakeholders involved and the values that stakeholder groups hold. Since stakeholder values may conflict, we also asked the authors to discuss the resulting value conflicts or dilemmas. The scope of responsible innovation emerges by discussing these aspects, which is needed to indicate how to define responsible innovation (our first research question). We also asked authors to describe how the dilemmas are dealt with in their case. Are distinct strategies adopted to innovate responsibly? Can typical innovation processes be distinguished that facilitate responsible innovation? Finally, we asked the authors to describe the practices, methods, tools and models that they adopted to analyse their case. The combination of these issues reveals how responsible innovation can be done in practice (our second research question).

In Table 1.1 we present the cases in the chapters and the discipline of their authors.

The cases refer to a large variety of societally relevant technological systems. The main focus in this book is on Dutch cases. However, we also discuss some international cases, such as nuclear energy (Chapter 5), wind power in the USA and in Denmark (Chapter 7) and frugal innovation (Chapter 6). Furthermore, Chapter 8 on responsible port innovation, although it focuses mainly on Dutch ports, contains a lot of insights on responsible port innovation in China.

Table 1.1 Chapters, cases and disciplinary backgrounds of the authors

Chapter	*Case*	*Disciplinary backgrounds of the authors*
2	Hydraulic engineering systems	Ethics, safety science, hydraulics
3	Smart meters in the energy system	Economics, energy systems, innovations studies, ethics
4	Shale gas	Political sciences, public policy, institutional economics
5	Nuclear energy	Ethics, innovation studies
6	Frugal innovations	Economics
7	Wind power	Economics, innovation studies
8	Port innovation	Cultural anthropology, sustainability studies
9	The good life	Economics, philosophy

1.5 Outline of this book

1.5.1 Plan of the book

In order to determine the order of the chapters, we considered how it would be possible to constitute a 'story-line'. We start the book with a relatively simple case of responsible innovation (Chapter 2), involving three ideas from the field of hydraulic engineering, which are still in the conceptual phase. For these ideas, possible impacts and possible stakeholders are described but there was no actual interaction between these stakeholders and the innovation yet. We then had each subsequent chapter introduce a new dimension to responsible innovation, which was not yet present in the preceding chapters. So, Chapter 3 introduces stakeholder debates on the smart meters in the electricity grid, Chapter 4 introduces intra-value conflicts emerging with the exploration of shale gas, Chapter 5 introduces emotions as an important indicator of moral value and it also introduces the interests of future generations that will experience the consequences of nuclear power systems. Chapter 6 further increases the stakeholder groups that need to be taken into account, applied to the case of frugal innovation for developing countries. The chapters are capped off by Chapter 7, which offers a relatively comprehensive view on all these dimensions by comparing three episodes of wind power development. Chapter 8 adds one more step by showing all these dimensions again, proposing a strategy to make an innovation process responsible which includes all these dimensions, and applying this strategy to the case of port innovation. Chapter 9 provides a unique philosophical approach to responsible innovation in terms of a conceptualisation of the good life. This chapter is not case-based but tries to outline the fundamentals of a theory of responsible innovation. Short summaries of the subsequent chapters are listed below.

1.5.2 Chapters

Chapter 2

In their chapter, Van Gelder, Doorn, and de Gijt discuss 'Responsible innovation in the hydraulic engineering sector' the practices and methods of responsible innovation in the hydraulic engineering sector. The authors indicate how values can be incorporated during the design stage of large hydraulic systems such as sluices, dunes and other waterworks, which belong to the vital infrastructure of our society. The authors describe and adapt a (semi-)quantitative tool that was originally meant to optimise maintenance. Three short case studies are described in which various dilemmas or conflicting values emerge. The chapter indicates how these dilemmas can be handled.

Chapter 3

In their chapter 'Responsible innovation for smart metering: An illustrative case study', Van de Kaa, Herder, Ligtvoet, and Lukszo describe how the government as

a regulator imposed a standard for the smart meter, which is a device that tracks energy use in households. In such a situation in which a system is imposed by government, the system would normally achieve instant market dominance. However, in this case potential consumers were not involved in the innovation process and, as a result, the smart meter was initially not accepted by consumers because important values, such as privacy, were not taken into account. The concerns among potential consumers made the Dutch parliament vote against the smart meter standard. Later, when changes were incorporated into the standard it did achieve market dominance. The case of the smart meter illustrates that important stakeholders cannot be ignored when developing or implementing an innovation because in that case the resulting innovation will not meet their values. If the stakeholders can convince parliament then even a government-imposed system can fail.

Chapter 4

Dignum, Pesch, and Correljé show, in their chapter 'Frames of reference and the interpretation of values in the Dutch shale gas debate', that energy initiatives often lead to public contestation, even when all actors support the same underlying values. The reason for contestation can be found in different interpretations of these values. Responsible innovation presumes a singular understanding of the values that underlie a new technology. Such an understanding is often lacking in the case of radically new technologies. Arguments presented in favour of or against shale gas exploration are connected to the expected impacts of this exploration on local/regional spatiality or on the (inter)national spatiality. Arguments that are put forward in either of these frames of reference are found to hardly connect to the other frames of reference. This chapter concludes that responsible innovation should acknowledge public values in all frames of reference in a symmetrical way.

Chapter 5

Taebi, Roeser and Van de Poel present a chapter titled 'Responsible innovation of nuclear energy technologies: Social experiments, intergenerational justice and emotions'. The authors argue that the concept of responsible innovation should be broadened in two respects. First, responsible innovation should be seen as an ongoing process that continues after the initial development of a new technology. This process calls for the social experiment as a tool to assess and shape the technological system while it is in operation. Second, emotions should be taken more seriously in responsible innovation because they can provide moral insights that can help in shaping the technological system. In addition to the two respects mentioned above, the authors believe that for technologies such as nuclear energy technologies – with very long-term risks – the value of intergenerational justice needs to be explicitly included in the decision-making process. These arguments have direct implications for nuclear power policies and help to move beyond the usual stalemate in the nuclear energy debate.

Chapter 6

Van Beers, Knorringa, and Leliveld examine in their chapter 'Can frugal innovations be responsible innovations?' under what conditions frugal innovations can be responsible innovations. Frugal innovations are (re)designed products, services or systems at substantially lower costs than 'standard' products, services or systems but without sacrificing user value. Responsible innovation involves taking into account ethical and social elements during development and production. Besides affordability and technological achievability successful frugal innovations are characterised by scalability. These characteristics do not automatically resemble the ethical and social elements that characterise responsible innovations. The central question is examined by focusing on two concepts: 1) social standards, and 2) inclusion of low-income consumers. Cases such as the frugal thermometer and frugal weather stations are used as illustrations.

Chapter 7

Ortt, Kamp and Künneke present a chapter titled 'How responsible was innovation in subsequent wind power episodes?' The authors explore how responsible the innovation process was during three episodes of wind power development: the American farm windmill between 1850 and 1880 in the USA, the direct current (DC) electricity wind turbine between 1890 and 1910 in Denmark, and the alternating current (AC) electricity wind turbine between 1940 and 1990 in the USA. The episodes turn out to be heterogeneous in terms of complexity and they vary significantly in terms of responsibility. However, the cases also yield common insights regarding responsible innovation. Firstly, responsible innovation is not just important prior to market introduction but remains important throughout the technology life cycle. Secondly, after introduction of an innovation, entrepreneurial activities and innovation efforts should be combined. The results of the analysis in this chapter indicate that different types of entrepreneurship and innovation processes can be distinguished, which can help to explain the different degrees of responsible innovation in the three episodes of wind power development.

Chapter 8

Ravesteijn contributes a chapter titled 'Responsible port innovation in the Dutch delta: the Maasvlakte 2 port extension project'. The challenges world ports face require new technological and institutional approaches of development and exploitation, aimed at promoting and implementing ecologically and socially sustainable port innovation and operation trajectories. This raises the question of how to deal with diverging, sometimes competing and even conflicting values in innovation and development processes. This chapter explores and refines a step-by-step responsible innovation process that deals with such issues. The process emphasises stakeholder involvement and process management methods, in

addition to design and expert methods. The Maasvlakte 2 project serves as a case. The focus is on the lessons to be learned, both for practitioners and academics.

Chapter 9

Naastepad and Mulder present a chapter titled 'How do we judge the responsibility (or otherwise) of research and innovation? Capital, Aristotle, and the neglected factor: freedom'. Missing in the debate on the 'responsibility' of research, innovation, and business is an examination of a possible conflict between the quest for 'responsibility' and the normative economic principles or 'micro-economic foundations' that guide the world's financial capital and therefore determine which businesses, innovations and research are funded and which are not. As a result, a lot of research and innovation that is deemed responsible will not materialise. The authors propose that such conflict can be resolved by re-examining our understanding of choice and capital, and by recognising the utilitarian foundation of mainstream economics – 'homo economicus' – as an unduly restrictive version of a wider Aristotelian understanding of choice.

Chapter 10 Conclusions

In the concluding chapter, contributions from all chapters are contrasted and combined where possible. Different definitions of responsible innovation, as proposed in the chapters, are compared. Is it possible to create a generic definition or should schools of thought be distinguished, each with their own perspective and definition? General practices and methods of responsible innovation that appear from the cases in the various chapters are summarised. Dilemmas and debates that emerge from the cases are described. How can we disentangle the dilemmas? Can we distinguish generic strategies to deal with these dilemmas? Finally, some ideas for future research are presented.

Note

1 We would like to thank three anonymous reviewers for their suggestions that contributed to this section.

References

Banta, D. (2009). What is technology assessment? *International Journal of Technology Assessment in Health Care*, 25(S1): 7–9.

Cervone, H. F. (2011). Understanding agile project management methods using Scrum. *OCLC Systems & Services: International digital library perspectives*, 27(1): 18–22.

Committee to Review the National Nanotechnology Initiative National Research Council (2006). *A Matter of Size: Triennial Review of the National Nanotechnology Initiative*. Washington: The National Academies Press.

Cooper, R. G. (2008). Perspective: The stage-gates idea-to-launch process—update, what's new, and NexGen systems. *Journal of Product Innovation Management*, 25: 213–232.

Cooper, R. G. (2014). Invited article: What's next? After stage-gate. *Research-Technology Management*, 57(1): 20–31.

Davies, A. (1997). The life cycle of a complex product system. *International Journal of Innovation Management*, 1(03): 229–256.

Davies, A., and Brady, T. (1998). Policies for a complex product system. *Futures*, 30(4): 293–304.

Directorate-General for Research and Innovation EU (2012). *Ethical and Regulatory Challenges to Science and Research Policy at the Global Level*. Brussels: European Commission.

Directorate-General for Research and Innovation EU (2013). *Options for Strengthening Responsible Research and Innovation Report of the Expert Group on the State of Art in Europe on Responsible Research and Innovation*. Brussels: European Commission.

Dubois, J. H. (1972). *Plastics History U.S.A*. Boston: Cahners Publishing Co.

Dyerson, R., and Pilkington, A. (2000). Innovation in complex systems: Regulation and technology towards the electric vehicle. *International Journal of Innovation Management*, 4(1 (March)): 33–49.

Edwards, P. N. (2003). Infrastructure and modernity: Force, time, and social organization in the history of sociotechnical systems. *Modernity and Technology*, 1: 185–226.

European Commission. (2012). *Responsible Research and Innovation. Europe's ability to respond to societal challenges*. Luxembourg: European Union.

European Union. (2014). *Rome Declaration on Responsible Research and Innovation in Europe*. Luxembourg: European Union.

Florman, S. C. (2000). Technology and the tragic view. In *Technology and the Future*, edited by A.H. Teich, Boston, New York: Bedford/St. Martin's, 50–58.

Friedel, R. (1983). *Pioneer Plastic*. Madison, Wisconsin: University of Wisconsin Press.

Friedman, B., and Kahn, P.H., (2003). Human values, ethics and design. In *Handbook of Human-Computer Interaction*, edited by J. Jacko and A. Sears. Mahwah, NJ: Lawrence Erlbaum Associates, 1177–1201.

Garcia, R., and Calantone, R. (2002). A critical look at technological innovation typology and innovativeness terminology: a literature review. *Journal of Product Innovation Management*, 19: 110–132.

Gokalp, I. (1992). On the analysis of large technical systems. *Science Technology Human Values*, 17(1 (Winter)): 57–78.

Grunwald, A. (2009). Technology assessment: Concepts and methods. *Philosophy of Technology and Engineering Sciences*, 2009: 1103–1146.

Hobday, M. (1998). Product complexity, innovation and industrial organisation. *Research Policy*, 26: 689–710.

Hughes, T. P. (1987). The evolution of large technological systems. In *The Social Construction of Technological Systems: New directions in the sociology and history of technology*, edited by W. E. Bijker, T. P. Hughes and T. Pinch. Cambridge, Massachusetts: MIT Press, 51–82.

Hughes, T. P. (1994). Technological momentum. Does technology drive history? In *The Dilemma of Technological Determinism*, edited by M. R. Smith and L. Marx. Cambridge, Massachusetts: The MIT Press, 101–113.

Miller, R., Hobday, M., Lerouxdemers, T., and Olleros, X. (1995). Innovation in complex systems industries: the case of flight simulation. *Ind Corp Change*, 4(2): 363–399.

Nasar, S. (2011). *Grand Pursuit*. New York: Simon & Schuster.

Owen, R., Stilgoe, J., Macnaghten, P., Gorman, M., Fisher, E., and Guston, D., 2013. A framework for responsible innovation. In *Responsible Innovation*, edited by R. Owen, J. Bessant and M. Heintz. Chichester: Wiley, 27–50.

Paul, S. and Singh, K. (2012). Be agile: Project development with scrum framework. *Journal of Theoretical and Applied Information Technology*, 40(105–112).

Perrow, C. (2011). *Normal Accidents: Living with high risk technologies*, Princeton University Press.

Peters, E. and Slovic, P. (1996). The role of affect and worldviews as orienting dispositions in the perception and acceptance of nuclear power. *Journal of Applied Social Psychology*, 26 (16): 1427–1453.

Rogers, E. M. (1986). *Communication Technology*. New York: Simon and Schuster.

Rogers, E. M. (2003). *Diffusion of Innovations*. New York: Free Press.

Schot, J., and Rip, A. (1997). The past and future of constructive technology assessment. *Technological Forecasting and Social Change*, 54(2–3): 251–268.

Short, J., Williams, E., and Christie, B. (1976). *The Social Psychology of Telecommunications*. Hoboken: John Wiley & Sons.

Sommer, A.F., Hedegaard, C., Dukovska-Popovska, I., and Steger-Jensen, K. (2015). Improved product development performance through agile/stage-gate hybrids: The next-generation stage-gate process? *Research-Technology Management*, 58(1): 34–45.

Stilgoe, J., Owen, R., and Macnaghten, P., 2013. Developing a framework for responsible innovation. *Research Policy*, 42(9): 1568–1580.

Tran, T. A., and Daim, T. (2008). A taxonomic review of methods and tools applied in technology assessment. *Technological Forecasting and Social Change*, 75(9): 1396–1405.

Van de Poel, I. (2016). An ethical framework for evaluating experimental technology. *Science and Engineering Ethics*, 22(3): 667–686.

Van den Hoven, J. (2013). Value sensitive design and responsible innovation. In *Responsible Innovation*, edited by R. Owen, J. Bessant and M. Heintz. Chichester: Wiley, 75–84.

Van den Hoven, J., Vermaas, P.E. and Van de Poel, I. (Eds.) (2015). *Handbook of Ethics and Values in Technological Design. Sources, Theory, Values and Application Domains*. Dordrecht: Springer.

Van Eijndhoven, J. C. (1997). Technology assessment: Product or process? *Technological Forecasting and Social Change*, 54(2–3): 269–286.

Veryzer, R. W. (1998). Key factors affecting customer evaluation of discontinuous new products. *Journal of Product Innovation Management*, 15: 136–150.

Von Schomberg, R. (2012). Prospects for Technology Assessment in a framework of responsible research and innovation. In *Technikfolgen abschätzen Lehren: Bildungspotenziale transdisziplinärer Methoden*, edited by M. Dusseldorp and R. Beecroft. Wiesbaden: Springer, 39–61.