5 Supporting RRI uptake in industry

A qualitative and multi-criteria approach to analysing the costs and benefits of implementation

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5.1 Introduction

Motivated by the need to ensure that research and innovation (R&I) activities are societally desirable, ethically acceptable and sustainable, the European Commission and funding agencies in some European Union Member States have made Responsible Research and Innovation (RRI) a vital pillar of their research funding initiatives over the last decade. A growing body of literature is dedicated to the development of conceptual frameworks for RRI, generally either focusing on the process dimensions of RRI (e.g., Stilgoe, Owen, & Macnaghten, 2013; Klaassen, Rijnen, Vermeulen, Kupper, & Broerse, 2019) or on the European Commission-defined keys (European Commission, 2014) to RRI (Klaassen et al., 2019). More recently, increasing efforts have been devoted to investigating what adopting RRI entails for industrial actors (Dreyer et al., 2017). As the field is still relatively young, most contributions focus on one or a few finely delineated aspects of what RRI implementation requires (e.g., van Wezel et al., 2017 on safety and technology assessment; Gurzawska, Mäkinen, & Brey, 2017 on incentives for RRI implementation) or on features relevant to RRI's uptake in one particular field (Chatfield, Borsella, Mantovani, Porcari, & Stahl, 2017, on risk perception in the ICT industry (Lees & Lees, 2018 on the sheep dairy industry). Thus, in reviewing the literature, recurrent lessons and themes, knowledge gaps and gaps between knowledge and implementation stand out (Yaghmaei, Porcari, Mantovani, & Flipse, 2019).

The literature shows that companies have both positive and negative attitudes towards RRI (Brem et al., 2017). Specifically, while alignment with societal needs and conducting oneself in an ethically acceptable manner are generally seen as key aspects of any R&I activity, companies often question the added value of RRI compared to existing practices, such as quality management or corporate social responsibility (CSR) practices, and how best to embed RRI in company operations (Porcari, Borsella, & Mantovani, 2015).

The lack of (management) models to evaluate and showcase RRI's added value is one of the barriers to fostering corporate commitments to experiment with and use RRI approaches. The aim of this chapter is to address this gap. Based on and inspired by literature on RRI, CSR and multi-criteria decision analysis (MCDA) and by practical experiences with pilot companies within the Horizon 2020-funded PRISMA project, which focused on promoting RRI in industry, we propose a practical model to help companies identify RRI implementation strategies during product development – connecting goals, actions and impacts – and a simple methodology to perform qualitative evaluations of its impacts (benefits, barriers and costs).

We subscribe to the conviction implicit in the very notion of RRI that value is gained by integrally considering all of RRI's diverse aspects. This chapter therefore aims to help companies, especially small and medium-sized enterprises (SMEs), to identify RRI implementation strategies that fit within their unique realities and constraints.

5.2 Methodology and context

This study's methodology and primary sources of data come from the PRISMA[1] project, a coordination and support action dedicated to exploring and promoting RRI in industry. Central to this project were eight pilot projects involving companies working on transformative technologies (nanotechnologies, synthetic biology and biotechnology, internet of things, drones and autonomous vehicles), which allowed us to test the implementation of RRI principles in industrial settings.[2] The pilot projects involved close interactions with the participating companies, revolving around their motivations for, attempts at and successes in operationalizing RRI in an innovation trajectory or on another level of company functioning. These pilot projects were the primary data source for our study. We used a wide variety of data-gathering methods, which are summarized in Table 5.1. Activities took place between January 2017 and December 2018.

5.3 Background

This section presents the background for our study, particularly those elements from the literature that we considered in our analysis of RRI, RRI in industry and CSR.

5.3.1 Responsible Research and Innovation and corporate social responsibility

Various conceptualizations of RRI circulate in policy and academic circles, each emphasizing different aspects.[3] Elements almost universally agreed upon include the ideas that RRI entails the continuous alignment of 'research and innovation to the values, needs and expectations of society'

Table 5.1 Primary sources for the study: the PRISMA project's most significant activities and a literature review

Step	*Description*	*Methods used*	*Main outcomes*	*Further details*
1	Tools and methods inventory	Desk research; semi-structured interviews with experts (n = 11) and EC project officers (n = 5)	Selection of decision-support RRI tools tailored to industry needs	Klaassen et al., 2016; Klaassen, Smit et al. 2017
2	Pilots for RRI implementation in industrial R&I projects on transformative technologies	Close interaction with eight companies during a two-year period (at least six semi-structured interviews per company)	Selection of RRI actions tailored to industry needs	Nathan, 2017, 2018a, 2018b; Guelke, 2018
3	Selection and reflection on KPIs for RRI	Desk research and interviews with pilot companies (one focus group with all companies and one semi-structured interview with each company)	Input to identify criteria to analyse the impact of RRI actions	Yaghmaei et al., 2019
4	Dialogues with stakeholders on RRI aspects related to the pilot projects and their tech fields[14]	Five dialogues involving more than 100 stakeholders (companies, industrial organizations, public research organizations, non-governmental and civil society organizations and experts in social responsibility and RRI); plenary and interactive sessions using workshop, world-café and fish-bowl methods to stimulate discussion. Some discussions were recorded and transcribed verbatim for content analysis using MAXQDA software	Input and review to identify and select RRI actions and criteria to analyse the impact of RRI actions	Maia & Coenen, 2017, 2018
5	Literature review	Review of scientific and grey literature based on a specific set of keywords[15] and excluding studies not focusing explicitly on industry	Thematic framing	See references

EC, European Commission; KPIs, key performance indicators; R&I, research and innovation; RRI, Responsible Research and Innovation.

(European Union, 2014, p. 1) and that RRI practices should feature the process dimensions of anticipation, reflexivity, inclusion and responsiveness (Stilgoe et al., 2013). For our study, we use the latter definition and do not delineate RRI more distinctly than that.

As researchers have observed, it is still unclear how the current concept of RRI can fit within the business context (Blok, Hoffmans, & Wubben, 2015; Lubberink, Blok, van Ophem, & Omta, 2017; Gauttier, Søraker, Arora, Brey, & Mäkinen, 2017) and questions remain regarding how issues of motivation and practical implementation should be addressed. A major issue, which is also found with CSR, concerns the conflict between a company's aspirations for monetary profits and market growth, on the one hand, and the extra costs associated with addressing social objectives such as sustainability, ethics and well-being, on the other (Iatridis & Schroeder, 2016). Another important issue is the lack of guidance (e.g. action plans) regarding how to put RRI principles into practice. This lack of support makes it difficult for companies to assess the expected impacts of RRI and, thus, to understand whether and how to embed RRI in their strategies.

Such uncertainties are one reason why the implementation of RRI in industry is still in its infancy. In fact, initiatives to practically implement RRI in industry are still limited, with most being related to cooperative projects within EU framework programmes or national equivalents.[4]

To foster the alignment of RRI principles and objectives with corporate strategies, it could be useful to look at RRI in relation to socially beneficial processes and tools that companies already know or have already implemented – usually under the label of CSR (Porcari, Borsella, & Mantovani, 2015; Iatridis & Schroeder, 2016; Chatfield, Iatridis, Stahl, & Paspallis, 2017). However, like RRI, CSR is a broad concept. In the present chapter, we look at CSR as a management concept promoting forms of self-regulation businesses use to improve their impacts in a socially responsible way, conventionally with a focus on people, planet and profit (Graafland & Smid, 2019).[5]

Given that policies are not always implemented – and even when implemented, they might not have the impacts desired – we do not make any assumptions regarding CSR's success or failure in realizing societally, environmentally or financially beneficial impacts. Likewise, we do not make any a priori delineation regarding the scope of CSR policies (i.e. do they incorporate research and development (R&D) and thus innovation, or not?). However, although CSR usually applies to a company's overall conduct – for example, human resource management, waste management, stakeholder engagement or communication – rather than its innovation or R&D activities, CSR processes or tools may well be applicable to innovation too. That can be expected to be the case at least insofar as both CSR and RRI relate (business) conduct to 'the responsibility of enterprises for their impacts on society' (European Commission, 2011, p. 6). CSR approaches provide guidance on principles, procedures and actions for implementing

CSR in a company's business operations. In addition, reporting and certification mechanisms are available to measure and showcase CSR performance, providing both a strong incentive for companies to implement CSR as well as support in doing so (Gurzawska & Porcari, 2016).

Garst, Blok, Jansen and Omta (2017) identified three types of motives that push companies to introduce CSR in their organizations: instrumental, relational and moral. Examples include reduction of production costs, increasing sales, postponing of legislation, attracting employees and investors (instrumental); fulfilling stakeholder expectations and being recognized for moral relationship (relational); recognizing the intentionality behind a product's long-term impacts, knowing a product's long-term impacts or attempting to attain that knowledge (moral). Although innovation presents its own specific issues, particularly because of the uncertainty that comes with it (Collingridge, 1980), most of these motives are also relevant for RRI. However, this similarity in motives does not necessarily translate into similarities regarding the responsibilities companies take on in their innovation activities and other business functions.

5.3.2 Issues regarding RRI implementation in companies

While CSR initiatives generally apply to the overall conduct of a company, the RRI concept focuses on the earlier phases of a product's development and life cycle and, thus, on the R&I stages (Gurzawska & Porcari, 2016; Chatfield, Borsella, Mantovani, Porcari, & Stahl, 2017). Introducing RRI could provide ways to anticipate social needs, concerns and challenges, and it could offer opportunities to increase product desirability and positive social impacts (and reduce risks) starting at the early stages of development. It could therefore avert late interventions and reduce overall product development costs (in an attempt to address the well-known Collingridge dilemma; Collingridge, 1980).

However, responsibility for RRI implementation cannot be limited to just those people working in R&I; it falls on all areas of a company. Chatfield, Borsella, et al. (2017) emphasized that, although R&D departments in highly innovative enterprises are considered one of the key departments where societal risks and ethical issues should be addressed and relevant stakeholders should be engaged, other areas are expected to play strategic roles in implementing RRI principles, particularly top management, human resources, CSR and legal functions and marketing.

Many studies suggest that an RRI approach should be conceived as a 'holistic' framework, given that RRI should be implemented along the entire R&I value chain and that management should disseminate RRI principles among all the people working inside or close to the company. In this regard, Lubberink et al. (2017, p. 23) wrote:

> The conclusion can be drawn that responsible innovation does not only ask for new corporate practice in terms of innovation activities, but

> it also demands that companies reflect on their business models, leadership, and their roles and responsibilities for the political and socio-economic system in which they operate.

Chatfield, Iatridis et al. underlined that:

> if RRI is perceived as being something that is 'bolted on' or in some way separate from the core activity of the company, then it will be difficult to achieve. For effective RRI, it may be necessary for the whole company to be on board.
>
> (Chatfield, Iatridis et al., 2017, p. 14)

During the PRISMA project's stakeholder dialogues, discussed in the methods section, participants confirmed that the endorsement of RRI should primarily be a strategic decision made by higher levels of a company's hierarchy, one that is then put into practice by the whole organization. However, stakeholders also discussed how this top-down approach could, in some cases, not be enough. Although a strong commitment from management is needed, the existence of an RRI promoter at other levels in a company (bottom-up approach) could be beneficial and used as a complement to the top-down approach.

5.4 The PRISMA model

Several studies, mainly in previous European Commission-funded projects, have aided the development of benchmarks for RRI practices, which have led to RRI criteria (Kupper, Klaassen, Rijnem, Vermeulen, & Jacqueline, 2003; Wickson & Carew, 2014) or indicators (Woolley & Rafols, 2016; MoRRI Consortium, 2018). Yet, RRI suffers from a lack of widely accepted RRI models that provide *practical guidance* in relating RRI principles to company goals, strategies and attitudes, as well as to technology and product features. Our reflection on the experience of RRI pilots with innovative companies (described in the methods section) taught us that such guidance is needed to help companies recast abstract RRI dimensions into a set of (management) strategies, tools and actions that can support and motivate all company departments in endorsing and adopting RRI. Practical guidance could also help provide ways to measure the impacts of RRI on company operations, thereby enriching the ongoing work on RRI benchmarks and indicators. A model that could play this role would also be a useful starting point for investigating the extent to which RRI could benefit from existing CSR practices and whether RRI could be integrated into those practices.

The PRISMA project developed a conceptual model for RRI implementation (van de Poel et al., 2017) that provides guidance to address the issues to consider in the implementation of RRI in industry. It is inspired by

three models developed in the context of the project Responsible Industry (Gauttier et al., 2017; Stahl et al., 2017) and provides a pathway for RRI implementation, represented graphically in Figure 5.1, that incorporates the following steps:

- *analysis* of RRI dimensions relating to the company's characteristics and values and the overall business and technology context to set the goals to be achieved through RRI
- *design* of the RRI strategy, defining the actions and tools needed to reach the goals, motivations and responsibilities and the desired level of RRI integration throughout the company's functions and the value chain
- *implementation* of those actions and tools in the different business areas and along the value chain
- *measurement and monitoring* of the impacts of RRI implementation to provide feedback for improving the strategy.

This set of steps is cyclic, meaning that it can be repeated to constantly improve the RRI strategy and actions to enhance the outcomes.

The PRISMA model follows a typical observe–plan–do–check–adjust (OPDCA) process (Smart, 2017). This is a variation of the plan–do–check–act/adjust (PDCA or Deming cycle) method already adopted in business contexts for the monitoring and improvement of processes and products.[6] The PDCA approach to RRI was previously proposed by other European Union-funded projects focused on RRI: SMART-MAP (Marschalek & Schrammel, 2018) and SATORI (*CWA 17145-2*, 2017). However, the OPDCA process emphasizes observation, a step often used in industrial contexts (e.g. in the literature on lean manufacturing, such as in the Toyota production system[7]).

Based on reflection on experiences with the eight pilot companies and the stakeholder dialogues, we aim to move beyond the PRISMA and Responsible Industry models in this study by distilling a set of RRI actions and criteria (and their relationships) that can support companies in assessing the impacts of RRI implementation on product development, at least qualitatively. Our goal is to provide a forward-looking approach to support RRI uptake in companies. In-depth analyses of PRISMA's activities and of the pilots in particular informed our results (for those analyses, see Maia & Coenen, 2017, 2018; Nathan, 2017, 2018a, 2018b; Guelke, 2018;).

5.5 The pathway for RRI implementation in companies

Defining suitable models for RRI implementation and methods for impact analyses needs to begin with an evaluation of the criteria for RRI uptake – the strengths and opportunities (benefits) and the barriers (risks, costs) of implementing RRI. This type of analysis (Section 5.5.1) provides information regarding the definition of an RRI action plan (Section 5.5.2) and the

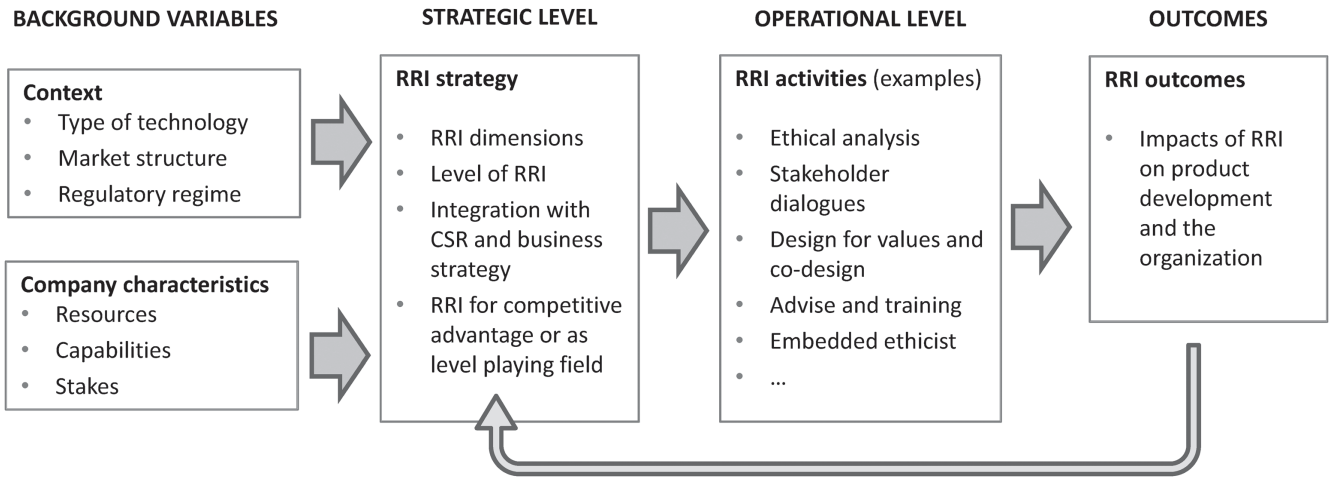

Figure 5.1 A conceptual model for Responsible Research and Innovation (RRI) implementation connecting the background variables, strategic level, operational level and final outcomes. CSR, corporate social responsibility. (Adapted from van de Poel et al., 2017.)

design of a multi-criteria and qualitative approach to analyse the impacts of RRI actions (Section 5.5.3).

5.5.1 Opportunities and barriers for implementing RRI

In analysing the experience of the eight pilot projects, we found that the costs related to RRI actions are generally perceived as being immediate, while most of the (positive) outcomes cannot realistically be expected until many months or even several years later (as in the case of company reputation). This perception is a major barrier to RRI implementation. However, when focusing on specific products, there are short-term RRI actions that can translate into immediate benefits, thus balancing the economic barrier of immediate costs versus deferred benefits. The PRISMA pilot projects provided examples of such actions, as reported in Guelke (2018) and Yaghmaei et al. (2019).[8]

The PRISMA pilots suggested that barriers to engaging with RRI exist at both strategic and operational levels and that these are not restricted to economic issues. In the PRISMA stakeholder dialogues, concerns over costs and resources associated with RRI were often mentioned by industry stakeholders, who raised issues about RRI being a difficult and bureaucratic process whose implementation would entangle internal and external resources. It was also clear that, once the companies became aware of the concept, RRI was perceived as potentially advantageous and as a possible way for them to save money. Most pilot companies agreed it would reduce several risks of product failure and would likely increase product acceptability. Other issues were also discussed:

- A company's 'maturity level' can influence its degree of interest in adopting RRI: a low awareness about responsibility or ethical issues could reduce this interest. Moreover, the pre-existing assumption of responsibilities within the CSR framework could reduce the perceived added value of RRI compared to current CSR practices.
- Identifying RRI approaches that fit a company's specific business case is not always straightforward, and thus, the related potential benefits might not be clearly visible. This calls for an interaction with experts or an in-depth reflection on company activities.
- Implementing RRI requires that a company opens its production processes and cooperates with different stakeholders in different phases of R&D. These actions could cause confidentiality problems and raise intellectual property rights issues that conflict with the company's usual management procedures.
- Developing a strategy for RRI adoption implies the internal agreement of several departments within the company and possibly a close cooperation between the R&D department and external partners along the R&I value and supply chains. This might be challenging.

- Specific skills for and experiences with RRI might be lacking within a company, and the use of external advisors and experts might be required. The more RRI is embedded in the existing process, the more this externalization could be resource demanding.

One influencing factor relates to the size of the company, which can strongly influence the possibility of investing in RRI activities. Large companies have several departments, each having different objectives and following specific formal procedures, and this complexity can challenge the introduction of new activities and procedures throughout the organization. However, big companies may already have some activities in place that support RRI or RRI-like principles at different stages of the value chain. Thus, it could be easier for them to integrate RRI concepts into existing procedures, possibly within their CSR framework. SMEs, on the other hand, have fewer resources to invest, but their organizational and decision-making processes are simpler: responsibilities are often shared across the company, which paves the way to an RRI implementation that involves the R&I value chain (at least within the company and with partners closer to the company). However, involving the entire value chain connected to product development might be more challenging.[9]

Regardless of their size, companies should monitor and evaluate the results of RRI adoption. The PRISMA project highlighted that, even if bigger companies can afford to use internal or external expertise for monitoring activities, both large and small companies would benefit from the availability of simple methodologies for self-assessment and evaluation that could provide constant feedback on the impact of implementing RRI.

Other factors influencing RRI implementation are closely related to the realities and constraints of the specific companies and sectors considered, including differences in the type of organization, the sector, the product and the technology considered. The main differences are found when comparing companies dealing with transformative technologies with those related to conventional technologies or traditional sectors. For instance, in one of the stakeholder dialogues, a participant from industry compared the example of nanomedicine, where transparency and openness are routine practices, with other sectors where the use of nanotechnology is sometimes hidden from product communication in order to avoid critical and opponent voices.

Innovative businesses are often more familiar with RRI concepts or activities. This can be due to a variety of factors:

- the need to foster customers' and society's acceptance of new technologies, which pushes companies to endorse specific values and adopt procedures for quality and social responsibility
- a strong willingness to intercept the public's needs and desires in order to facilitate access in the market of new technologies

- the uncertainties in normative requirements often associated with new technologies.

Some telling examples of RRI aspects already embedded in company operations were seen during the PRISMA experience, namely, the identification of companies' core values (such as quality, knowledge and sustainability) and companies' compliance with certifications for quality, environmental protection, health and safety, ethical aspects, sustainability and the like, in connection with R&I products.

Dialogue initiatives, performed on a regular basis with a wide range of stakeholders, were also mentioned as actions already implemented to build trust and relationships, improve transparency, develop common understandings and inform the political and societal debate. Finally, life cycle assessments, eco-design, sustainability strategies toward compliance with the United Nation's sustainable development goals (SDGs), responsible manufacturing and supply chain management were also identified as RRI-related activities already taking place in some companies.

Companies using transformative technologies have to deal with uncertainties and thus are looking for novel and advanced methods of risk and quality management, ones that are more responsive to users' needs and perspectives. RRI can be helpful in addressing these aspects.

One example of how RRI can improve responsivity comes from the PRISMA pilot projects involving nanomedicine – a rapidly transforming sector in which the emerging ethical and societal issues are critical to its eventual success. Because of the ethical and societal implications of new and challenging health therapies, which are sometimes personalized, companies require support from RRI approaches in dealing with patients and healthcare professionals and, more generally, with public opinion. A comment at one of the stakeholder dialogues attests to this: 'This is the responsibility for industry: to communicate in a proper way the benefits, but also the risks. … This can be managed with a proper Responsible Innovation strategy'.[10] Thus, a therapy's acceptability could strongly benefit from RRI actions that encourage a process of product 'co-creation' that includes all the involved stakeholders and from transparency in communications about the real cost–benefit ratio for the patient.

Based on the experience with the pilots, and literature on RRI implementation in industry (e.g., Chatfield, Borsella, et al., 2017),[11] PRISMA developed a strengths, weaknesses, opportunities and threats (SWOT) analysis to help companies compare the human and economic efforts required for RRI implementation with the benefits and opportunities, such as profits, efficiency or public image (reported in Porcari, Pimponi, Borsella, & Mantovani, 2019). We used this SWOT analysis and the reflections discussed in this section to inform the definition of RRI actions (Section 5.5.2) and the selection for criteria for the assessment of RRI impacts (Section 5.5.3).

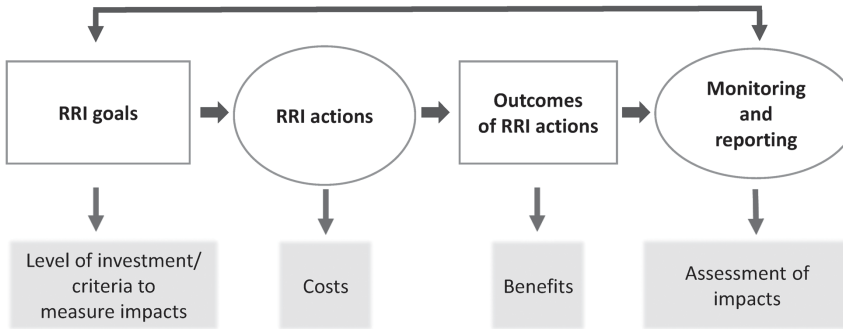

Figure 5.2 Responsible Research and Innovation (RRI) implementation phases and relative steps for impact evaluation (a cyclic approach).

5.5.2 Setting the strategy for RRI implementation

Based on the issues and models for RRI implementation discussed in the previous sections, we created a conceptual map to support development of an RRI implementation strategy. The map in Figure 5.2 includes and links the following elements:

- the actions required to reach the desired RRI 'maturity' or 'performance' level in every dimension of RRI
- the responsibilities needed for RRI deployment, with respect to the different company functions
- the organizational and financial impacts of these activities inside and outside the organization
- the relevant – qualitative and quantitative, tangible and intangible – criteria to assess the impacts related to RRI.

RRI impact analyses can be performed for specific products/projects or for overall R&D activities, and they can be done in a procedural/formal way or a more informative/informal way, depending on the conditions and needs of the company. Regardless of their target or method, impact analyses will likely include these main steps:

- defining the target (level of maturity/commitment/investment to achieve in RRI) and selecting criteria for monitoring costs and benefits based on the RRI goals and strategy
- estimating costs based on the RRI action plan and tools
- evaluating benefits based on (expected or actual) RRI outcomes
- monitoring RRI implementation based on selected criteria and using the results to continuously refine the RRI goals, strategy and indicators.

Given the broad and diverse impacts that RRI could have on an organization, as shown in Section 5.5.1, impacts should be evaluated on a case-by-case basis. Note that the overall impact of an RRI implementation strategy could actually exceed the sum of the specific benefits derived from each action.

A cornerstone for impact evaluation is the defining of a concrete action plan for RRI. Based on our experiences with the PRISMA pilot projects, we identified three key actions relating to the different RRI dimensions:

1. Reflection and anticipation ('observe/plan'): Integrate analysis of ethical, legal and social impacts (ELSI) beginning in the early stages of product development.
2. Inclusiveness ('do'): Perform stakeholder engagement to inform all phases of product development.
3. Responsiveness ('check/adjust'): Integrate monitoring, learning and adaptive mechanisms to address public and social values and normative principles in product development.

As indicated, the order of these actions follows an OPDCA cycling process. Tables 5.2–5.4 provide examples of how these three key actions can be used for implementing RRI in product development at the company level, with reference to expected benefits, the R&I value chain, the corporate functions, the stakeholders involved and the investment term. Further information on the strategy selected by each of the PRISMA pilot projects, including their RRI actions and expected benefits, is reported in Porcari et al. (2019).

5.5.3 Using a multi-criteria and qualitative approach to analyse impacts of RRI actions

Given the difficulties in defining and measuring relationships between actions and impacts, methods such as cost–benefit analysis and cost-effectiveness analysis seem difficult to apply to RRI, at least given the current level of RRI knowledge and practical experimentation in industrial contexts. Instead, MCDA (Linkov et al., 2006) may be more effective in evaluating the broad and diverse impacts related to RRI. MCDA is typically used to choose between different alternatives, considering multiple criteria on different scales or of various natures. With MCDA, impact categories (called lines of evidence) and criteria for each category are identified in accordance with the specific case. A scoring system is used to evaluate qualitative and quantitative impacts against the criteria, and weights can be applied to each criterion. This kind of analysis provides a qualitative or semi-quantitative comparison of impacts between different RRI adoption scenarios.

This section provides company project/product managers with a simplified MCDA model for self-evaluations of the positive impacts (benefits),

Table 5.2 Reflection and anticipation actions for integrating analysis of ethical, legal and social impacts (ELSI) throughout all stages of product development

Actions	*Benefits*	*R&I value chain phase*	*Corporate functions involved*	*Stakeholders involved*	*Investment term*
Conduct ethical analysis, through foresight, scenario analysis, social phenomena and trends evaluation, etc.	Improve product quality, desirability and acceptability Improve product sustainability, safety and reliability Address uncertainties, prevent and mitigate risks Motivate workers	Basic and applied research, engineering and testing	Management, R&D	R&I partners, end users, policymakers	Short, medium
Design for values, stakeholder and value inventory/scenarios (values hierarchy, conflicting values, etc.)			R&D	R&I partners, suppliers, end users	Short, medium
Include RRI principles in company's mission and vision			Management, R&D	Internal to the company	Medium
Hold internal meetings with R&D personnel to reflect on ethical issues			R&D	Internal to the company	Short
Solicit ELSI advice from (independent and external) experts as needed			R&D, CSR, legal	Internal to the company	Short

Table 5.2 (*Cont.*)

Actions	*Benefits*	*R&I value chain phase*	*Corporate functions involved*	*Stakeholders involved*	*Investment term*
Develop and introduce ethical frameworks, codes of conduct		All	Management, legal, R&D, CSR, quality	Internal to the company	Medium
Implement life cycle assessment (LCA) and social LCA		Applied research, engineering and testing	Management, R&D, quality, CSR	Suppliers	Long
Re-evaluate expected impacts prior to market launch				Internal to the company	Short

CSR, corporate social responsibility; R&D, research and development; RRI, Responsible Research and Innovation.

Table 5.3 Inclusiveness actions for stakeholder engagement that inform all phases of product development

Actions	*Benefits*	*R&I value chain phase*	*Corporate functions involved*	*Stakeholders involved*	*Investment term*
Set and implement a communication and dialogue strategy on ELSI	Strengthen relations and trust with all stakeholders, network building	Engineering and testing, go to market	R&D, CSR, marketing	All	Long
Work with business and social actors sharing values and create positive ethical networks	Reconcile opposing views and bridge opposing values New values creation Anticipate potential regulatory change Product quality, desirability and acceptability	All	CSR	All	Medium
Co-design product through dialogue with policy actors, authorities and normative bodies (EU, regional and local)		Applied research, engineering and testing	R&D, quality, legal	Policymakers, regulators	Short
Organize public dialogues, build/use public platforms for expressing needs and concerns			R&D, CSR	End users, consumers	Medium
Connect to or organize living labs and social experimentation using participatory methods			R&D, CSR	End users, consumers	Short, medium

Table 5.3 (*Cont.*)

Actions	*Benefits*	*R&I value chain phase*	*Corporate functions involved*	*Stakeholders involved*	*Investment term*
Build user-based communities of practice			R&D, CSR	End users, consumers	Medium
Promote initiatives for social inclusion, provide consumers with an official role in the innovation process		All	CSR	End users, policy makers	Medium
Promote capacity building with vulnerable actors in the value chain		Engineering and testing, go to market	R&D, CSR	End users	Medium

CSR, corporate social responsibility; ELSI, ethical, legal and social impacts; R&D, research and development; RRI, Responsible Research and Innovation.

Table 5.4 Responsiveness actions to integrate monitoring, learning and adaptive mechanisms that address public and social values and normative principles in product development

Actions	*Benefits*	*R&I value chain phase*	*Corporate functions involved*	*Stakeholders involved*	*Investment term*
Integrate user-centred design, user innovation, flexible and adaptive design, co-creation approaches	Create value, increase the social value/ impact of R&D Build corporate image and reputation	Applied research, engineering and testing	R&D, management, legal, marketing	R&I partners, supply chain suppliers, end users, consumers	Long
Screen suppliers for positive practices	Compliance with qualified norms and standards			Suppliers	
Put procedures in place for investigating reports of concerns or misconduct			Management, legal	Internal to the company	Medium
Employ adaptive risk management	Facilitate the access to financial support		Management, R&D, quality	Internal to the company	Medium
Embed ethicists in the R&I process		All	CSR, R&D	Internal to the company	Medium
Establish an ethical, social and legal (ELSI) monitoring board		All	R&D, management	R&I partners, suppliers, policymakers, end users	Long
Include ELSI criteria in internal procedures for R&D project quality monitoring		Applied research, engineering and testing	R&D, management	Internal to the company	Short
Perform regular ethical review and get ethical certification (by independent bodies)		Engineering and testing, go to market	CSR, quality	Certification bodies, regulators and authorities	Long

(*continued*)

Table 5.4 (*Cont.*)

Actions	*Benefits*	*R&I value chain phase*	*Corporate functions involved*	*Stakeholders involved*	*Investment term*
Obtain social accountability and quality certification at company and supply chain levels			CSR, quality	Certification bodies, regulators and authorities, investors	Long
Monitor post-marketing ELSI impacts		Go to market	R&D, quality	Regulators and authorities	Long
Include ELSI for R&D and innovation products in CSR/ sustainability reporting			CSR, marketing	All	Long
Support and invest in sustainable supply chains		All	R&D, management	Suppliers	Medium
Select funding mechanisms based on ethics/responsibility requirements		All	R&D, management	Funding bodies, investors	Short

CSR, corporate social responsibility; R&D, research and development; R&I, research and innovation.

negative impacts (barriers) and costs/resources resulting from RRI actions in product development.

As previously discussed, RRI aspects are connected to a broad spectrum of factors related to the type of company and its management style, the technology and products it works on, the sector and market, the pertinent regulatory frameworks and the stakeholders involved. Also, the conditions for RRI uptake relate to various issues, spanning from long-term strategic factors at the company level (e.g. company reputation) to short-term factors in product development (e.g. alignment with user needs and stakeholder values).

Analyses of RRI uptake should consider both tangible and intangible short- and long-term impacts and are therefore quite complex. We propose a qualitative methodology, focusing on individual projects or products, that looks at multiple criteria and is based on the RRI actions discussed in the previous section. The proposed self-evaluation procedure for companies contains four steps:

1. identification of a set of RRI actions for product development (RRI strategy)
2. evaluation of the impacts of the RRI actions based on selected criteria. Impacts could be positive (benefits of RRI uptake), irrelevant or negative (barriers to RRI uptake)
3. evaluation of the direct costs of performing each of the RRI actions (high, medium, low) compared to product development costs
4. mapping and analysis of the overall impacts of RRI uptake on an evaluation matrix.

This exercise can be used to assess the impact of actions taken or to evaluate different RRI strategies before implementation in order to identify the most advantageous and cost-effective actions for RRI uptake with respect to the selected criteria.

Tables 5.2–5.4 provide many examples of RRI actions that could be used in step 1 of the self-evaluation procedure. However, a company might decide to focus on a smaller or larger set of actions depending on its conditions and goals. Ideally, though, it should focus on having at least one action for each table in order to fulfil all the RRI dimensions. The final action plans in the PRISMA pilot projects included four to nine RRI actions per pilot company, with an emphasis on inclusiveness and responsiveness actions.

Table 5.5 provides a model questionnaire for a company's self-assessment of the impact of RRI actions. The questionnaire is structured as a set of five questions (Q1–5) that are based on lines of evidence (LoE), as described in Section 5.4, plus a sixth question (Q6) related to the direct costs of RRI actions. Each of the first five questions is detailed by a set of sub-questions (criteria) derived by criteria for RRI implementation that were discussed in Section 5.5.1. Though both Q5 and Q6 involve financial aspects, Q5 refers

Table 5.5 Questions and sub-questions (criteria) proposed for a company's self-assessment of the impacts (benefits, barriers, costs) of Responsible Research and Innovation (RRI) actions

Main questions (Q)	*Criteria*	*Impact of RRI action(s)*
Q1: Scientific and technological line of evidence (LoE)	Q1.1: Inspire technological innovation Q1.2: Feasibility of the technology solution Q1.3: Product quality (performance/ efficiency) Q1.4: Product reliability Q1.5: Extend the product life cycle Q1.6: Trust with/avoid conflicts with business partners, suppliers, end-users	Positive Irrelevant Negative
Q2: Ethical and societal LoE	Q2.1: Product acceptability Q2.2: Product safety Q2.3: Product environmental sustainability Q2.4: Effect on quality of life and health of customers Q2.5: Product-related services and guidance (e.g., ethical protocols) Q2.6: Address users' needs and rights (e.g., privacy, data ownership, etc.)	Positive Irrelevant Negative
Q3: Strategic LoE	Q3.1: Competitive advantage Q3.2: Corporate image Q3.3: Transparency on product qualities Q3.4: Customer satisfaction, meeting new consumers' needs or requests Q3.5: Build legitimacy and gain consumer loyalty for the product Q3.6: Improve relationships with partners, suppliers and sub-suppliers Q3.7: Fulfil ethical and social requirements (e.g., for access to funding)	Positive Irrelevant Negative
Q4: Organizational LoE	Q4.1: Allocation and deployment of resources (e.g., human resources) Q4.2: Team cooperation and motivation for product development Q4.3: Address regulatory barriers Q4.4: Risk management, safety at the workplace Q4.5: Gender and diversity contribution to product development Q4.6: Avoid irresponsible behaviour	Positive Irrelevant Negative

(*continued*)

Table 5.5 (*Cont.*)

Main questions (Q)	*Criteria*	*Impact of RRI action(s)*
Q5: Economic LoE	Q5.1: Product cost Q5.2: Time to market Q5.3: Profit, market penetration Q5.4: (Favoured) access to financial support Q5.5: Use of human resources	Positive Irrelevant Negative
Q6: RRI action costs	Q6.1: Direct costs to perform the RRI action (compared to product development costs)	Low Medium High

to economic criteria related to product development (e.g. time to market), while Q6 refers to the costs of performing the RRI action (e.g. conducting stakeholder engagement activities, establishing an ethical and social advisory board, hiring an 'embedded' ethicist in product development).

The PRISMA pilot companies considered the most significant criteria for each LoE to be the following (Porcari et al., 2019):

- (Q1) inspire technological innovation, product quality and reliability
- (Q2) product acceptability and safety, address user's needs and rights, trust with/avoid conflicts with business partners, suppliers and end-users
- (Q3) build legitimacy and gain consumer loyalty for the product, meeting new consumers' needs or requests, transparency on product qualities
- (Q4) address regulatory barriers, risk management
- (Q5) market penetration, use of human resources.

RRI costs were a significant issue for only a few of the pilot companies.

To use the questionnaire, product/programme managers should evaluate the impact each RRI action would have on each criterion, using a three-score scale (positive, neutral/irrelevant or negative for Q1–5; low, medium or high for Q6). An example outcome is provided in the self-assessment matrix in Table 5.6 (based on a generic set of three possible RRI actions: A1, A2 and A3). Note that, instead of using scores, the evaluation could be visualized by using emoticons (a 'sentiment analysis'[12] technique), to facilitate qualitative comparisons of results.

In this example, RRI action 1 (A1) would have a positive impact from the scientific and technological (Q1) and ethical and societal (Q2) points of view; its impact would be irrelevant at the strategic (Q3) and organizational (Q4) levels, but negative at the economic (Q5) level. The direct cost (Q6) of the action would be low or negligible. A2 would provide the same beneficial impacts, but with an irrelevant impact at the economic level, whereas

Table 5.6 Example of a self-assessment matrix for the overall impact of possible Responsible Research and Innovation (RRI) actions, based on specific criteria for product development

Impact of RRI actions on criteria	*Impact of RRI A1*	*Impact of RRI A2*	*Impact of RRI A3*
Q1: Scientific and technological line of evidence (LoE)	Positive	Positive	Irrelevant
Q2: Ethical and societal LoE	Positive	Positive	Positive
Q3: Strategic LoE	Irrelevant	Irrelevant	Positive
Q4: Organizational LoE	Irrelevant	Irrelevant	Positive
Q5: Economic LoE	Negative	Irrelevant	Positive
Q6: Direct costs of the RRI action	Positive	Positive	Negative

A3 would have positive impacts on four lines of evidence, and no impact on the remaining line. However, the costs for its implementation would be quite high.

These results suggest that A2 should be implemented, while implementing A1 and A3 might be challenging due to their negative economic and cost impacts. However, A1's and A3's results are not necessarily as negative as they may seem at first. In fact, although the two actions have negative financial impacts, the mixed impact of the other categories may well outperform the financial impacts and therefore give a green light to the overall RRI strategy.

After beginning with this simplified methodology, companies should identify a more quantitative set of indicators to refine the scoring system and to develop and apply more complex and in-depth MCDA.

5.6 Discussion and conclusion

This chapter proposes a practical model to help companies to identify RRI implementation strategies during product development, and offers a simple methodology for a first, qualitative evaluation of RRI impacts along the lines of benefits, barriers and costs. Based on experiences from PRISMA pilots as well as other European Commission-funded projects on RRI in industry, it includes a selection of RRI actions that exemplify how RRI principles can be put in practice.

The PRISMA experience suggests that RRI could help companies that deal with disruptive technologies improve the societal impacts of their innovative products. But to do so, RRI needs to be implemented from the early stages of development onwards and should be considered as a medium- to long-term investment. The model proposed in this study offers a path for that implementation. Moreover, the PRISMA pilots also indicate that success of RRI uptake is strongly context-dependent and is affected by several factors, including company size and organizational complexity and

the level of innovation and its associated risks. Our analysis suggests that the benefits of RRI can be both tangible and intangible and short-term and long-term. Prominent barriers include the immediate human and financial resources required to operationalize RRI.

The strengths of this model are that it provides a hands-on approach, that helps to ensure that RRI implementation fits as much as possible within the realities and constraints of individual companies. It is based on widely recognized management approaches (SWOT, Deming cycle) and is flexible and modular in order to accommodate differences across sectors, technologies and types of companies. The model makes use of the 'RRI maturity level' concept, thus giving the opportunity to integrate and consider any company activities that already address RRI aspects, including existing risk, quality and social responsibility actions ('de facto' RRI). Moreover, the model presented here provides a way to assess the impacts of RRI actions on product development, and it is complementary to the development of key performance indicators for monitoring RRI at the organizational level.

However, the model was derived through reflection on experiences with a limited number of pilot projects (and for a limited period), and although companies participated on a voluntary basis, their activities were driven and supported by the resources and targets of the PRISMA project. Testing on real cases, designed to fit the needs, requirements and timelines of a specific company or project (e.g. a task or work package within an industry-led R&I action), is necessary to further develop and refine the model, as well as ways of implementing it. Analysis of different types of companies (e.g. size, sector) and innovations (e.g. technologies, stage of development) would also be instrumental to making further progress in the field.

The approach presented in this study will become a part of a pre-standard document developed as a European Committee for Standardisation (CEN) Common Workshop Agreement (titled 'Guidelines to develop long-term strategies (roadmaps) to innovate responsibly'). This broader document, which will include experiences from other projects and initiatives, will be targeted towards any kind of organization dealing with R&I.[13]

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Notes

1 www.rri-prisma.eu

2 The organizations involved in the PRISMA project were: Hub of All Things (UK), Aerialtronics (NL), Spectro (NL), RDM Group (UK), Colorobbia Consulting (IT), Laboratori Archa (IT) and Evolva (CH). The eight pilot projects were a public–private partnership linked to a cooperative project called Bisigodos (UK).

3 For instance, see Von Schomberg, 2012; Stilgoe et al., 2013; Van de Hoven, 2013; Klaassen, Kupper, et al., 2017; Gianni, Pearson, & Reber, 2019. Probably the most contested yet possibly most influential conceptualization is the one put forward by the European Commission (2014) in which RRI is defined in terms of the commission's six keys to RRI: ethics, gender, open access, governance, science education and public engagement. For criticism of this conceptualization, see, e.g., Klaassen, Rijnen, Vermeulen, Kupper, & Broerse, 2019.
4 For more information on such programmes, see www.nwo.nl/onderzoek-en-resultaten/programmas/maatschappelijk+verantwoord+innoveren (accessed 10 October 2018) and www.nwo.nl/onderzoek-en-resultaten/programmas/maatschappelijk+verantwoord+innoveren (accessed 10 October 2018).
5 CSR can simultaneously be seen also as (1) a (cynical) discourse used to legitimize the status quo in industrial conduct and consolidate the power of big firms (Banerjee, 2008) and (2) an academic research field in which the social responsibility of firms is studied either descriptively (Ritala, Huotari, Bocken, Albareda, & Puumalainen, 2018) or normatively (Blok, 2019).
6 The Deming cycle is currently used in standardization: for example, in the ISO 9001 quality management system and the ISO 14000 series on environmental management. See www.iso.org
7 See Rother (2010) for more information on this example.
8 For example, in the pilots on nanotechnologies, introducing specific procedures for the safe use of nanomaterials in production phases increased the safety and sustainability of products; promoting stakeholder dialogues improved understanding of consumers' expectations and helped to address normative and market requests, such as alignment with distributors' requirements for 'premium' consumer products.
9 These considerations are strengthened by the outcomes of the Delphi study conducted in the Responsible Industry project and reported in Porcari et al. (2015).
10 Direct quotation (line 109) from a business and industry participant at the 1st PRISMA Stakeholder Dialogue, 'The Future of Technology: Putting Responsible Innovation into Practice', held in Brussels on 13 April 2017.
11 For example, the literature provided by previous RRI-related projects (such as Responsible Industry, MoRRI, Proso, Satori and COMPASS).
12 A 'sentiment analysis' aims to determine the subject's attitude regarding a specific topic or the emotional reaction to a document or an event. The attitude could be an emotional state but also a judgement or evaluation.
13 For more information, see www.cen.eu/news/workshops/Pages/WS-2019-010.aspx
14 See Maia and Coenen (2017) for detailed information on strategy and methodology for these events. See Maia and Coenen (2018) for a report on the events.
15 Keywords used in the literature search: RRI, CSR, industrial research, responsible innovation, business practices, social innovation, sustainable innovation, innovation management, governance, entrepreneurship, innovation process, R&D management, corporate shared values, ethical leadership, SDGs, business ethics, responsible investments, innovation ecosystem, business strategy, industrial pilots, social impact assessment.

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