ANNEX 1

REELER's Methods and Methodology

Annex 1: REELER's Methods and Methodology

1.0 REELER's Methods and Methodology

Interviewer: Do you think it would be useful to work with, to collaborate with social scientists or is there no need?

Giovanna: I think it would be useful to also have persons with such a focus. With their background, but also with this sort of interest [in robotics]. Otherwise, they seem very distant to me.

(Giovanna, Robot Developer, Regain)

REELER (Responsible Ethical Learning with Robotics) is an H2020 project funded by the European Commission,[1] running from January 2017 to January 2020. In this document, we elaborate the methods and methodology behind our ethnographic and economic research. For other project activities, please visit the Outreach and Research sections of the REELER Roadmap (*see http://responsiblerobotics.eu*).

The project is an ethnographically led project, which set out to explore ethics in robotics through a new method of 'multi-variation' (Hasse 2019); an anthropological inquiry across a variety of cases into the people that make robots, the people affected by them, and the relational responsibility between them. It is an example of how anthropology, making use of ethnographic methods, can find patterns across a number of detailed studies of how robots are developed, how users of robots are envisioned, and how notions of users can be expanded (*see Perspectives on Robots (responsiblerobotics.eu/perspectives-on-robots*).

Furthermore, REELER is a highly interdisciplinary project involving four European partners from the fields of anthropology, learning, robotics, philosophy, and economy: Coordinator Cathrine Hasse, Aarhus University, Denmark; Partner Maria Bulgheroni, Ab.Acus. srl, Italy; Partner Kathleen Richardson, De Montfort University, United Kingdom; Partner, Andreas Pyka, Hohenheim University, Germany. During the project's life-span more than 40 hardworking post docs, research assistants, student helpers and translators have helped produce, translate and analyze data from 11 robot case studies in 15 Northern, Southern, Eastern and Western European countries.[2] REELER's high level of multidisciplinarity aims at cooperation, comprehension and acceptance of SSH-research in the robotics research community. The project's research aims at aligning robot makers' visions of a future with robots with empirically-based knowledge of human needs and societal concerns through a new proximity-based human-machine ethics (depicted in the Human Proximity Model (see the Introduction to *Perspectives on Robots*) that takes into account how individuals and communities connect with robot technologies. The project's ethnographic research has been focused on everyday decisions and practices in robot development, the collaborations that make development possible, and the learning that occurs (or does not occur) in these processes. The project's economic research (see section four) combines economic data with ethnographic data, as well as modelling and data visualization to explore research and development processes and the effects of robotization.

2.0 Ethnographic research methodology

The core of the REELER project is ethnographic fieldwork in robotics laboratories and offices, as well as on-site ethnographic studies and impact studies of present and potentially affected stakeholders. REELER conducted three 6-month rounds of reeling fieldwork and analysis, producing 11 case studies covering different robot types, application sectors, countries, and organization types.

A multi-variation cross-case analysis led to the findings presented in the project's final output, the REELER Roadmap (*see responsiblerobotics.eu*) – which is not a traditional roadmap, but a winding road to new insights. The methods and methodology behind these case studies are described in depth in this document in the section on ethnographic research.

1 The REELER project received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731726 (for more information see www.reeler.eu).

2 In no particular order Stine Trentemøller, Karolina Zawieska, Ben Vermeulen, Maja Hojer Bruun, Niels Christian Mossfeldt Nickelsen, Jamie Wallace, Louise Bøttcher, Mia Mathiasen, Christina Leeson, Donovan Anderson, Kane Carreras-Gogh, Kate Davis, Valentina, Simonetti, Alex Gimondi, Walter Baccinelli, Alejandra Gomez, Sara-Lynn Lepage, Sophie Urmetzer, Lila Anne Todd, Christian Djerving, Stephan Hansen, Wienke Reimer, Jessica Sorenson and Sebastian Madsen + 15 translators.

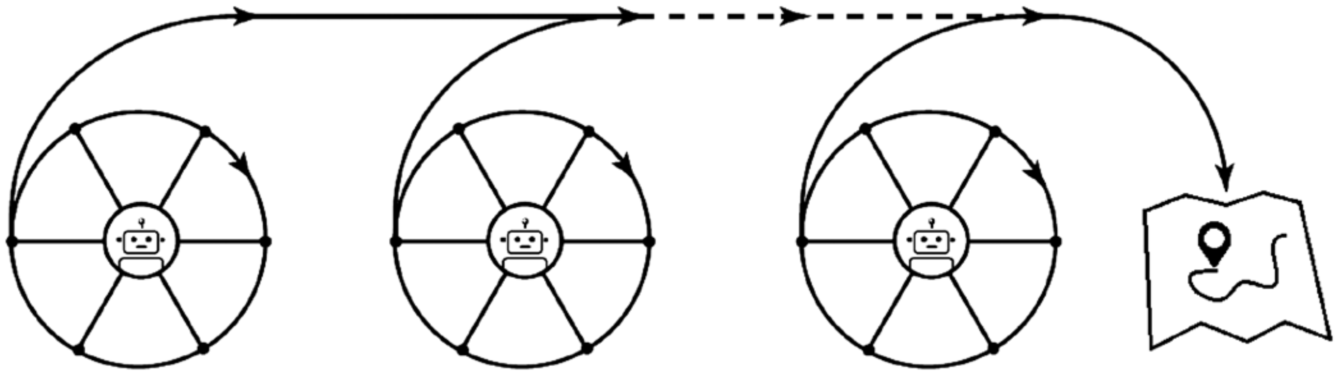

Figure 1. Illustration of the applied methodology of 11 case studies reeling toward the final roadmap.

Our research methods and methodology has evolved since the beginning of the project January 2017. Therefore, we shall here attempt to give an overview of the complex process that we've taken with our Grant Agreement (No 731726), Milestones and Deliverables as measuring sticks, while all the time letting project findings influence our envisioned goals and aims.

In the first section, we give an overview of the joint tasks undertaken in the project's first period, January 2017 to July 2017. In the second section, we give an overview of the ethnographic studies, conducted from January 2017 to December 2018, and the subsequent NVivo-based analysis of the ethnographic data (July 2018 to July 2019). In the third section, we describe the collaborative analysis of the project's collective research, leading to the joint interdisciplinary publication Perspectives on Robots, the BuildBot game and the interactive Toolbox and other outreach tools (available in the REELER Roadmap). Here we also discuss the methodological challenges. Finally, in the fourth section we introduce the economic research conducted fom January 2018 to July 2019.

2.1 Preparing the Common Ground

The REELER project aims to raise awareness of the human potential in robotics development, with special attention to distributed development, relational responsibility, ethical and societal issues, collaborative learning, and the economic and societal impacts of robotization. These findings are summarized in the final output of the project, the REELER Roadmap (*see responsiblerobotics.eu*) which includes an awareness-raising toolbox, the publication *Perspectives on Robots* with ethical guidelines for Human Proximity in robot development, as well as recommendations for policy makers and robot developers for how to include the voices of new types of users and affected stakeholders.

With the aim of producing this Roadmap for responsible and ethical learning in robotics, REELER developed a comprehensive research methodology that blends ethnographic research with engineering insights and economic data on research and development, agent-based modelling, and experimental methods for collaborative learning. Our first task was to establish a common ground and a shared vocabulary among the researchers in the very interdisciplinary group. Here we drew on concepts developed by Anne Edwards on *relational agency*. Edwards (2005) argues that relational agency means "a capacity to align one's thought and actions with those of others in order to interpret problems of practice and to respond to those interpretations" (pp. 169-170).

This was operationalized in the project as an attempt to share conceptual understandings – even though we come from various fields. We have attempted to understand each other's disciplinary vocabulary (across engineering, anthropology and economics) by, among other things, defining the key terms we work with (*see Annex 3 of Perspectives on Robots*). Therefore, we began the project by discussing the relevant concepts across our different disciplines: robot, ethics, innovation networks, collaborative learning, on our joint knowledge-sharing platform, SharePoint – some of which can be found in our research repository as well as in Annex 4.

We had decided early on that each researcher would conduct their own fieldworks – however, we would also work together on robot cases. We had also decided to choose cases in relation to the multi-variation method, which entailed a robot mapping of where there were robot laboratories in Europe.

The REELER project began with a **mapping** of robot makers in Europe, while we also did **open field research** in the robotics community, and **literature reviews** of core research concepts.

These initial activities informed the development of REELER's shared research protocol.

From these three activities, REELER developed a shared research protocol which included a theoretical framework, and a best practices guide to ethnographic fieldwork, including ethical guidelines for conducting research, qualitative interview guides, and data processing and handling procedures.

Here forward, REELER entered the research phase, which consisted of **economic research** including patent analysis, agent-based modelling, and analyses of economic data on research and development practices and **ethnographic research** (case studies centered on robots, those making robots, and those affected by robots). During this phase, REELER pioneered several **experimental outreach methods**, which provided some input to the research, but also served as tools for engaging various stakeholders about new robot developments and their effects.

In the beginning of the fieldwork period beginning approx. August 2017, we had developed our guidelines for:

1. Conducting research ethically and with a basis in the multi-variation method, which entailed identifying robots of different types in development in different countries and in different types of companies. During the first and second year of REELER a huge variety of robots developers across Europe were identified, and condensed into 11 case studies.
2. In order to identify patterns across the variation (see Hasse 2019) we also create systematic case write-ups that followed the same structure from case to case.
3. This made it possible to identify themes in each case, which were then either found, or not found, to be repeated in the subsequent cases. In the 'reeling methodology', we kept finding new themes in the case write-ups – and could go back and forth between the cases to see if these were new or recurrent patterns.
4. We also identified and defined our main groups of interviewees: the robot maker and the affected stakeholders (two groups that were later broken down in our work of analysis and expanded in the Human Proximity Model).

All of these guidelines, for interviews and case write-ups, can be found in our joined *Best practice research and observation guide* in REELER's Research Repository.

All this preliminary work took place during the first period (January – July 2017). By then we had conducted a number of smaller pilot studies, in Germany where we found the most robot companies, and in Cyprus where we found only four, in order to identify what should go into the joint best practice research protocol. Simultaneously we worked on our first case study, of the health care robot REGAIN, as a pilot where we developed the guidelines together.

In the following sections, we describe the work we did in the first period in more detail.

2.2 Literature search and reviews

The first period of open research helped us identify key analytical concepts and empirical topics that would guide our research. As part of the REELER project's efforts to develop common ground within the project, researchers performed 14 literature searches and comprehensive reviews of these topics, which were later discussed at seminars. These concepts broadened and deepened understandings of the empirical field and laid a framework for analysis.

2.3 Robot mapping

In order to gain an overview of robot development activities in Europe, REELER researchers examined robotics associations (e.g., euRobotics), market reports (e.g., International Federation of Robotics), and directories of robot developers, integrators, and suppliers (e.g., the Robot Report). From this overview, we were able to categorize robot makers by organization type (university, research institute, startup, manufacturer, etc.) and to categorize robots by type and application sector. We also began to identify clusters and trends in regional robot development (e.g., social robotics in Spain) and identified four factors that differentiated robot makers: country or region, robot type, application sector, and organization type. The factors that sprang out of the robot mapping were the starting point for our case selection criteria for the ethnographic case studies.

We identified a number of different robot types – and decided to cover them all in our cases except marine, space and army robots.

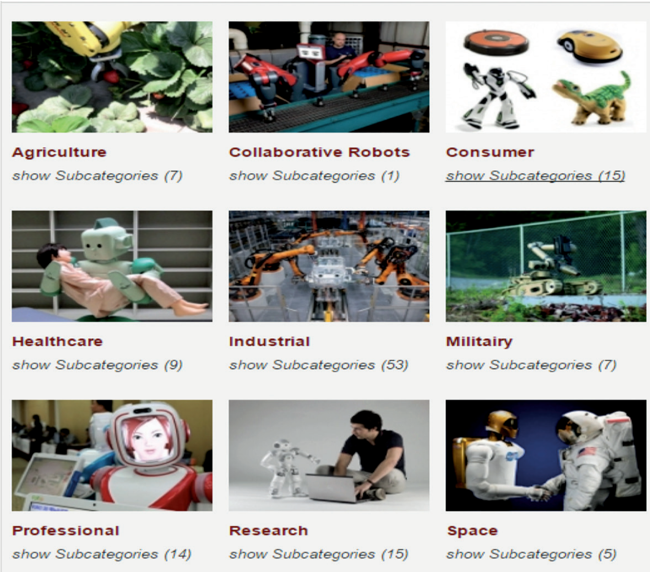

Figure 2. Identification of various robot types based on EuRobotics' typology

Many robot developers participate in organizations like euRobotics (internationally) or RoboCluster (nationally) – and following this we both decided to let their organisations guide us in finding robot companies as well as made it clear we needed to participate in the robot fairs and conferences organised by these organisations.

In terms of our initial mapping of robot companies we for instance found to our surprise that of the 250 members organised in *euRobotics,* 52 are German organizations, making Germany the most represented country in this organisations. The same tendency was seen in other parts of the field of robotics under the EU. Among *Robotics Today's* 200 members, 47 are German companies, indicating that Germany is also highly involved in the private robotics community. However, we also found substantial robot communities in Northern, Western and Southern Europe, whereas the Eastern European companies lagged behind other parts of Europe in terms of a critical mass of robot developers. To seek variation we decided to make all parts of Europe represented in our case selection.

(*See robot mapping reports in REELER's Research Repository – responsiblerobotics.eu/research/repository).*

2.4 Open field research

Having gained some insight into the distribution of robotics development across Europe, REELER endeavored to understand more intimately the community and culture of robotics and the actors involved (i.e. who makes robots, where do they meet, how they collaborate) and to gain access to potential participants for our ethnographic case studies. Therefore, REELER researchers attended conferences, visited laboratories, toured factory halls, and made some pilot interviews in Germany, Cyprus and began our first case study of REGAIN – a health care robot. These experiences helped shape the fieldwork procedures and interview questions we would later adopt for the ethnographic fieldwork through the **Best practice research and observation guide.**

More importantly, this period of open field research helped us to further develop some common language and basic knowledge of robot makers' worlds so that we had a sufficient starting point for our inquiries.

3.0 Experimental outreach methods

Furthermore, the project made use of novel methodologies to give both robot makers and affected stakeholders a space for mutual exchange about a robotic future, built around a number of REELER's ethnographic case studies of robots being developed in Europe. These novel methods include experiments with mini-publics, design games, and dramatic methods (including REELER's own social drama and explorations of the established Sociodrama approach with professional sociodramatists).

1. *Mini-publics* A forum for knowledge transfer and debate, where the general public are invited to learn about and discuss targeted issues pertaining to a given topic presented by experts in that field.
2. *Action methods* Established and new experiments in dramatic methods, Sociodrama & Social Drama are used for perspective taking and reflection on one's own practices.
3. *Design games* BuildBot and Brickster are games that allow players to reflect on responsible robotics by selecting design features that fulfill needs expressed by different stakeholders.

These developments of these experimental methods provided input into REELER's ongoing economic and ethnographic research, but were also refined based on the findings of this research.

Read more about REELER's outreach tools in the REELER Roadmap (*see http://responsiblerobotics.eu/outreach*).

4.0 Conducting ethnographic research

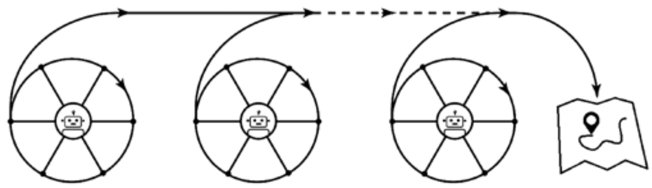

Figure 3. Illustration of the applied methodology of 11 case studies reeling toward the final roadmap.

REELER's methodology is defined by the 'reeling process': finding themes case study by case study to identify common themes across the varied robot types, robot collaboration and varied national identities of robot developers and affected stakeholders.

The data of the multi-sited cases are generated through ethnographic fieldwork. Ethnographic research is a process of discovery, termed "wayfaring" by Tim Ingold (2011), guided by the ethnographer's prior knowledge. As with the selection of field sites and participants, the ethnographer remains open to the unexpected (DeWalt & DeWalt 1998), but also navigates the field, making strategic selections in methods and leads to follow. In the REELER cases, the researchers used qualitative interviews, participant observation, and document analysis, including internet research and visual imagery.

4.1 Case study approach

The REELER project applies a multi-sited case study methodology (Gerring 2006; Marcus 2005), with the cases built around particular robots. Participants were chosen in relation to each robot type, and field sites were drawn around selected participants tied to the development of a specific robot within the chosen robot type. For example, in the agricultural robot case (our fourth case study), the researcher identified a case that included a lab and robot coordinator with a nationality not already covered and a collaboration type not already covered in previous case studies. We met with robot makers in their laboratories, and in their offices. Tracing out the connections to the robot, the researcher met the farmer buying the robot, who knew about farming (and thus acted as an application expert in our Human Proximity Model (in the inner circle of robot makers). However, we also met the farmworkers (affected stakeholders) at the test site. In this case, there was a general understanding of the robot makers that the robot would fit all types of farming environments. Drawing out the connections further, the researcher identified a number of sites in Southern Europe, where the robots would not seem to fit in. We met with affected stakeholders at these sites and, following presentations of the robot, discussed how these robots would affect them and make them 'distantly affected

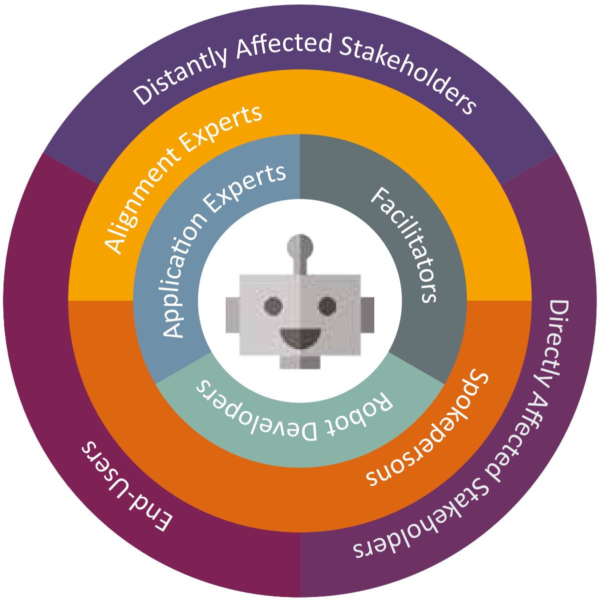

Figure 4. The Human Proximity Model

stakeholders' in our Human Proximity Model. For reasons of non-disclosure (which means we cannot reveal the actual name and function of the robot) we cannot directly quote the affected stakeholders in this case study, but we can refer to our outreach tool *mini-publics (see responsiblerobotics.eu/outreach/mini-publics)*, where some of these findings were presented in de-identifiable form. Here, considerations such as the following were voiced:

"Huge potential for highly mechanized farming system. However, what about rural poor farmers? Problems of access, lack of knowledge, maybe even no electricity available."

"Dexterity, flexibility, speed, etc. of robots is poor in unstructured environments and with highly variable tasks, so productivity will drop"

We also met with other robot makers, whose work is related to, but not directly connected to, this particular project. In all of our cases, our researchers began with a robot, and then mapped the network of people who made the robot and/or who might be affected by the robot's implementation.

Interviews were conducted and each case was carefully written up following the templates in the *Best practice research and observation guide*. Below we describe our work on the cases more in detail.

4.2 Case selection

Between January 2017 and December 2018, REELER researchers conducted 11 ethnographic case studies, beginning with our pilot studies and first case study REGAIN. Each case started around a single robot representing a robot type (e.g. construction, agriculture, health care etc.) and sometimes expanded to include robots of the same type and sector in order to ensure anonymity and greater cross-case validity.

Case robots were selected according to information-oriented selection criteria, for maximum variation and for strategic importance to the general problem: "To maximize the utility of information from small samples and single cases. Cases are selected on the basis of expectations about their information content," (Flyvbjerg 2006, 230).

With this in mind, REELER first mapped robots all over Europe, across various industries, and with various applications, and with varying levels of human proximity. Cases were crafted to be representative of the wide variation identified in the field.

REELER's multi-variation approach (Hasse 2019) included selection for diversity with regard to:

1. *Nationality*. REELER conducted fieldwork in 13 of 28 EU member states, including robots from both robot-heavy and robot-light countries across Europe: Austria, Belgium, Cyprus, France, Denmark, Germany, Ireland, Italy, Netherlands, Poland, Portugal, Spain, UK.[3]
2. *Type of robot*. Eleven cases were built around a variety of robot types, including both industrial robots and service robots, but also variation within these categories to include collaborative robots, social robots, humanoids, etc.
3. *Sector*. REELER opted to exclude military, space, and undersea robotics for reasons of access and ethics. REELER's case robots were applied in different sectors: autonomous transport, logistics, construction, service, SME manufacturing, production, healthcare, agriculture, civil infrastructure, cleaning, and consumer/education.
4. *Organization type/funding*. The cases were initiated by different robot makers (each with their own motives), including public funding organizations, industry associations, start-ups, SMEs, university researchers, etc.

In the end, REELER conducted 11 cases across 7 sectors (11 subsectors), in 13 different European countries. Several robots comprise each case. These cases are referenced throughout the REELER Roadmap by case names (e.g., CO-BOT) which refer not to a specific robot, but to a specific case built around a specific *robot type and application sector* (e.g., collaborative robots in manufacturing).

REGAIN is a case built around healthcare robots of different kinds, e.g., feeding assistive devices, rehabilitation, and social care robots.

ATOM is a case built around consumer robots, specifically social robots applied in the education and entertainment sectors. This case includes robots designed for use by children.

BUDDY is a case built around commercial service robots, including humanoid social robots applied and used for research

3 Pre-Brexit

at universities, but also used in exhibitions, at hotels and in shopping malls.

COBOT is a case built around collaborative robots used in SME manufacturing. These are primarily lightweight articulated arms built into larger robotic cells, but also include drilling or welding robots.

COOP is a case built around robots used in production, e.g., assembly, including industrial robots, but also 'uncaged' robots.

HERBIE is a case built around automated transport, e.g., autonomous cars and automated guided vehicles, especially those intended for passenger transport.

OTTO is a case built around inspection robots, e.g., for construction, maintenance, and repair - in public transportation systems, for instance.

SANDY is a case built around agricultural robots, e.g., for harvesting, planting, or milking.

SPECTRUS is a case built around service robots used for industrial cleaning, e.g., in hospitals, hotels, warehouses, or airports.

WAREHOUSE is a case built around logistics robots in warehouses, e.g., for transport and organization of goods.

WIPER is a case built around robots used at construction sites, e.g., for heavy lifting or laying tiles.

A more detailed overview of REELER's cases can be found in the robot concept review and typology provided in Annex 4 to the publication *Perspectives on Robots* (*see http://responsiblerobotics.eu/Annex-4*).

4.3 Participants

As our fieldworks developed, we learned that we might have problems keeping participants de-identifiable if we took only one robot as a case study of a particular robot type. From our robot mapping, reviews of the different robot types *(see Annex 4),* and through participation in conferences etc., we identified supplementary robots within each case where we conducted supplementary interviews with robot developers – sometimes later in the process without including these interviews in the case study descriptions. This is why we ended up with 160 interviews in our Nvivo database, whereas 17 interviews can be considered supplementary material.

Thus, learning from our previous fieldworks, we broadened the scope of field sites to allow our case studies to comprise more than one robot and robot company, as long as the field sites were relevant to the primary robot, e.g. by being of the same type, or operating within the same industry, etc. Broadening the scope in this way helped us to meet the demand for anonymity from our participants. In our the latest case study, we also turned the tables, and took the affected stakeholders as our point of departure for the ethnographic research after we had identified the robot type – and only later made interviews with the robot makers.

We had two approaches to participant selection in the field. The first, a reflexive "bottom-up" approach began in the field with open questions and observations, and resulted in a selection of affected stakeholders, e.g. working for different hotels, resorts, or cleaning companies. The second, a more structured "top-down" approach, began by gaining access through a gatekeeper who then selected participants and arranged the fieldwork on behalf of the fieldworkers, resulting in more organization but less freedom in the fieldwork. Sometimes the robot developers themselves brought specific affected stakeholders to our attention, but we always tried to bring in new voices that the engineers had not envisioned themselves would be affected by their robots.

We identified affected stakeholders both through the top-down and bottom-up approach, but particularly in the SPECTRUS case, we identified affected stakeholders before the robot makers. This gave us the possibility to take a point of departure in the experiences of cleaning staff in Denmark and Portugal. However, throughout the project, and especially in the first fieldwork period, we increasingly tried to give more voice to the most vulnerable persons affected by robots (i.e. people with low job-security and little education), as their voices may rarely be heard in political discussions of why and how robots should take part in our (work)lives. In addition, for the stakeholders we tried to seek variation in relation to level of education, type of employment, nationality, and gender. Nevertheless, the selection of participants, both among the robot makers and affected stakeholders, reflects the gender imbalances in particular industries (*see chapter 5 Inclusive Design* and *chapter 11 Gender Matters*).

In the first round of cases, the selection of participants began with a selected robot and its gatekeepers (those granting access to the network of people around the robot). From these initial meetings, the researchers recorded the history of the robot's development and mapped the network of people involved. However, their selection of participants and field sites was not linear, but occurred in a rather explorative, 'reeling' process in which new information from one encounter opened up to the next. Take, for example, this description of participant selection from one researcher's field notes:

I started by interviewing the robot maker and coordinator at [the lab where the robot is being developed]. He suggested a visit to [a site] where the robot has previously been tested. Going there, I interviewed a partner and grower and asked permission to work [at his site] the following day and interview some of his employees, which he permitted. Talking with the grower, I learned about the differences in practices in the [north and south of Europe]. This information made me curious to explore what the attitudes toward [the robot] were in the south part of Europe, given that their current cropping system might not be *able to use the robot. For this reason, the next field trip became the south of Europe. My translator introduced me to a friend, a woman that used to work in the agriculture industry packing vegetables for a large export company. She had useful connections in the industry and facilitated contacts with workers.*

This approach relates to our aim to expand the notion of the user and of human proximity - to seek out those who are affected by the robot, even if they do not encounter the robot in their everyday lives.

In the later fieldwork periods, the selection of participants began instead with an identified robot type and potentially affected stakeholders (hotel cleaners, labour union representatives, e.g.). Like in the previous fieldwork period, participant selection occurred in a rather explorative, 'reeling' process in which new information from one encounter opened up to the next. However, unlike the previous fieldworks, the researchers made efforts to begin with an affected stakeholder oriented approach to build an understanding of how these groups of stakeholders worked and of what their values, interests, and concerns were, so that the researchers could utilize this data in the robot maker interviews, before returning again to stakeholders. This approach relates to our aim to bring forth stakeholder voices and to narrow the gaps in proximity between robot developers, policymakers, and affected stakeholders.

The robot makers in every case were selected for their role in developing the robots in question, but also for their relevance to the case – i.e., those who may encounter similar technologies in their line of work. Selected affected stakeholders included both those involved in robot development, testing the robot, or as well as persons who work in the sector and may potentially use the robot in the future, or who may be otherwise affected. All participants took part voluntarily and signed consent forms acknowledging the scope and conditions of their participation. Some participants required legal agreements (non-disclosure agreements, e.g.), which is discussed further in the section on methodological challenges.

The diversity among those selected reflects the actual diversity of those involved in robot development or in the application sector (e.g., construction, agriculture). Across cases, we more than interviewed 160 participants; roughly half of these were robot makers and the other half were affected stakeholders. Robot makers were primarily engineers, primarily male (roughly 80%), with university education or higher, and most were white Europeans (which we describe in the Human Proximity Model as belonging to the 'inner circle'. There was a wide variation in ethnicity and education level among affected stakeholders, from those who had never finished primary school to those with advanced degrees. There were significantly more non-European or immigrant Europeans among affected stakeholders than found in the group of robot makers, particularly in the agriculture and cleaning cases. (*See chapter 3 Collaboration in the Inner Circle*)

There were more female robot makers in healthcare robotics and the 'softer' side of robotics (e.g., human-robot interaction, user studies). Participating affected stakeholders were majority male (roughly 60%), though this varied greatly by occupation. For example, the leader of the hospital cleaning department in the SPECTRUS case described her staff as "99% female", while construction and factory workers were almost exclusively male. We did not seek complete parity, but let the actual reality mirror our choices of gendered informants. Yet, we began to actively seek more female participants as robot makers as we gradually realized, we needed their voices – however it was not an easy task.

Read more about participant diversity in Chapter 11 Gender Matters (*see responsiblerobotics.eu/chapter-11*) of the publication *Perspectives on Robots*.

4.4 Data collection methods

Access to participants and recruitment process. In general, the entire sampling and data collection process led to redefinition of parts of the REELER analytical framework developed prior to starting the fieldwork. Above all, it required refining the categories of 'Robot makers' (R) and 'Affected Stakeholders' (AS) and in some cases allowing for classifying single study participants and their roles as both R and AS. In addition, the scope of each case was broadened to go beyond a single robot around which a given case was built around and cover multiple countries and related extended networks within one case if needed. This was to increase the variety of the study participants and inclusive selection procedures as well as meet de-identification and confidentiality requirements. The category of being 'European' in terms of nationality, origin of the company or funding also become looser. As discussed below, one of the biggest challenges in REELER fieldwork was in finding access and right arguments to recruit study participants, as well as deal with the related constraints.

Establishing contact. In the start of the project, we did exploratory fieldwork to establish contacts, to identify potential cases for study, and to gain common ground across disciplines within the REELER team. This work was critical to grounding the fieldworkers in the field with an initial understanding of the languages, cultures, and norms within robotics communities. Having this base knowledge made it less problematic to gain access to the field (the chosen environment and its inhabitants' life-worlds) when building our cases. Nevertheless, each new field site required the fieldworkers to gain access anew.

Gaining access and developing rapport and trust with the participants, so that they might be open to ethnographic enquiry, is time-consuming work that involves introductory conversations and meetings and encounters within professional spheres (conferences, expos, etc.). We made use of the exploratory fieldwork done (at ERF 2017, e.g.) to identify relevant sectors and robots for our case selection. Indeed, one of the cases was facilitated by a contact made in at these events and another by a contact from our outreach activities.

Ethical principles and anonymity. Since the REELER researchers gather both sensitive personal data and business sensitive data, it is important for the project to comply with both the ethical principles of ethnographic work (e.g. ASA Ethical Guidelines 2011;[4] See also REELER's Best Practice Research and Observation Guide) (*see http://responsiblerobotics.eu/research/reeler-research-repository*).

Moreover, we adhered to the principles of non-disclosure negotiated with each collaborating partner/company. All participants sign an interview consent form and get to approve the transcription of their interview. In that process, they can indicate if certain parts must not be disclosed.

Although all cases had some degree of sensitive material, they ranged from highly confidential to completely open. Where some interviewed robot makers have asked for full anonymity both regarding their own identity and the robot project they are involved in, REELER and the fieldworkers have signed non-disclosure agreements (NDAs) which cover a wide range of information (particularly, but not only, visual information) about the robot, its developers, and the settings of development or intended implementation. Where participants have requested that both gathered ethnographic data and references to public information about the given robot be anonymized for internal use, including in reports like this one, to the European Commission, REELER has furthered efforts to de-identify all persons and projects in the presentation of data and preliminary findings.

In REELER's public material, we give pseudonyms for the actual robot names and person names, somewhat decontextualize empirical material, and make minor edits to quotations to preserve anonymity. When such anonymity is promised, we have generally experienced that the robot makers are very willing to participate in our study. Among the affected stakeholders, the request for full anonymity has been less outspoken, yet in some cases, the affected stakeholders have been wary of giving interviews, seemingly in fear of losing their jobs.

4.5 Qualitative interviews

The researchers conducted qualitative interviews in a way that elicits rich narratives, in order to "understand the world from the subjects' point of view, to unfold the meaning of peoples' experiences, to uncover their lived world" (Kvale 1996). Interviews were conducted using a semi-structured interview guide and using visual elicitation methods (showing videos of a robot to prompt discussion).

Interview guides Interviews were conducted according to the interview guides and recommendations from the *Best Practice Research and Observation Guide.* The interview guides used were divided into three main sections, focusing on:

1. participants' life-worlds, their (professional) use of technologies, and their perceptions of, and encounters with, robots;
2. reflections/assumptions/expectations elicited from viewing public imagery of a specific robot; and
3. new reflections/assumptions/expectations in response to confidential imagery of a particular robot.

(See REELER's semi-structured interview guides in the REELER Research Repository.)

Researchers followed the interview guides, but asked questions out of order and adapted questions to accommodate the different flows of the individual interviews. Some sections or questions of the robot maker (robot maker) interview guide were not at all relevant to particular interviewees, so these were abbreviated or omitted in certain interviews. For example, those involved late in the development process (such as system integrators/business/sales) were not even involved in the project's design phase. With later interviews where we had already obtained so much background information about the design, we moved more quickly through some questions and used the opportunity to enrich our data with other relevant questions and elaborations. However, the questions we used to go across cases with were asked in most cases (with a few slippages).

We also added questions in relation to specific cases and questions we learned were of relevance and wished we had included in the beginning. For instance, the question of universal basic income to affected stakeholder, became relevant to add after learning (from our previous cases) that many robot makers presented their robots as relieving workers of monotonous and arduous labour, and sometimes suggesting basic income or reskilling as a solution for displacement/replacement. By asking affected stakeholders about giving up their work for a basic income, we hoped to explore their motivations for working, beyond money (*see also Chapter 10 Meaningful Work – responsiblerobotics.eu/chapter-10* – in the publication *Perspectives on Robots*). One question to affected stakeholders that initiated fruitful conversation about robots was: *Why do you think [this robot] was created?* Motivations, concerns, and interpretations come through with such a question.

The diversity of our participants and their experiences made it necessary to remain flexible in the interview process, sometimes for some time departing from the guide entirely to get the conversation flowing before returning to the guide to ground the interview again. This method was particularly useful for getting the participants to talk more freely and begin relating to their own lifeworld.

One reflection we had from the beginning was that it could be good to have a similar visual or material tool for starting a conversation around ethics. Therefore, we had in our protocol that participants should be shown pictures of movies of the robots in question. Due to the non-disclosure agreements, we had to give up this plan, but in many cases we still managed

4 www.theasa.org

to let participants ponder over pictures or movies presenting similar robots.

Overall, our interview process revealed the diversity of our robot maker participant group and highlighted the need for future ethical toolkits/guidelines to address engineers, designers, and other robot makers as particular and idiosyncratic groups with different experiences and comfort levels in working with social science themes. Furthermore, it demonstrated how our initial biases about robot makers had shaped our interview guide and how with the progression of REELER's fieldwork, we came to consider them more as a heterogeneous group. Lastly, it brought forth questions about the dynamics between the different types of robot makers in a project or workplace: What are the decision-making processes and power relations between them? *What is the culture of the workplace around ethics and design and how do the different robot makers shape this culture? And, how can REELER best address these culture-shapers?*

We began our project with two groups: the robot makers and the affected stakeholders. However, the reality of who made robots and whom they affected turned out to be more complicated.

We ended up identifying three main groups of people involved in robot making: 1. The actual developers – mainly engineers and software programmer involved in lab work, 2. The application experts, the people helping the robot developers develop knowledge of the sites where the robots were thought to be implemented – for instance a warehouse manager or a hospital manager.3. The facilitators, by which we mean the funding agencies and graphical designers, etc. helping to finance and sell robots.

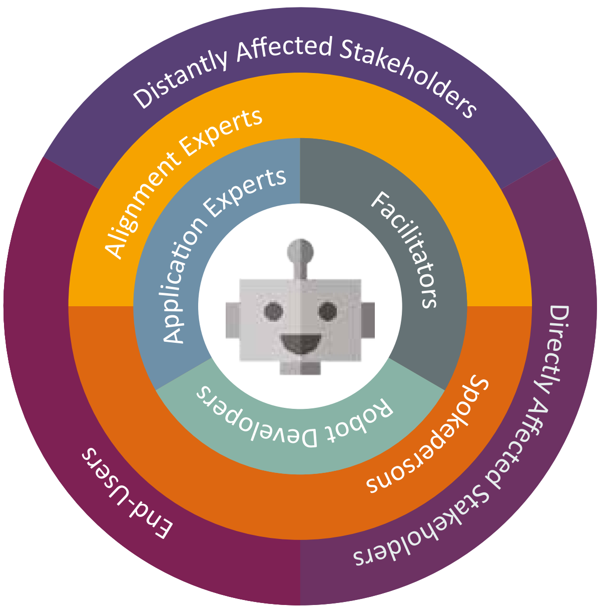

Figure 5. The Human Proximity Model

More to our expectations also the affected stakeholders turned out to be a very varied group – and at first we had troubles identifying some of the affected stakeholders from the application experts. This meant that we for instance had a hospital manager or an owner of a big farm listed as an affected stakeholders – even if they worked with the robot developers. Only gradually did we note that these people 'spoke' for the people who were actually going to work with the robots – the real end users, and that the robot developers themselves often mistook these influential persons, or 'spokespersons' as end users. Furthermore, we found out during the first fieldworks that that people who were affected by robots were not just the end users. There were always many people around them who were also affected. Furthermore we found affected stakeholders who never touched the robot but were nevertheless affected by it (for instance because the introduction of robots in their fields meant they had to take a new education). Thus, we needed to refine our categories of affected stakeholders as well. The first group in closest proximity to the robot were the actual end-users, the people operating or working directly with the robot. The second group were all the people directly involved in material and social arrangements around the robot – for instance the nurses helping the patient (the envisioned user of the robot). This group was systematically overlooked by robot developers in our cases. Finally, as mentioned, we identified big groups of affected stakeholders who are never in contact with the robots but were nevertheless distantly affected by them.

4.6 Observations & field notes

Participant observation and field notes. While participant observation is a mainstay of ethnographic research, we encountered significant barriers to traditional ethnographic observations in REELER. Most of the robots studied were developed in labs and transported to test sites, sometimes actual sites of implementation but in many cases the developers re-constructed human environments in laboratories reflecting where the robots would eventually be implemented. In some cases, due to confidentiality restrictions, the researchers were not permitted access to the actual robot under development, but were shown video recordings and images of previous models instead. In other cases, the development of the robot interfered with observation settings, as the testing periods were repeatedly delayed and rescheduled partly because the test-users cancelled testing appointments. A robot maker explained that since construction workers are working on piece rates, it is difficult for them to test the robot because the process delays their work:

It was still not super-fast because [the construction worker] was careful, of course, but he got some sense of how to do and they actually thought it was an okay product. He just thought it was difficult to do it fast. They could do it faster themselves so therefore they would lose money if they were to work with it. … In the end, our manager asked them, what if you get it and were asked to use it for a week? They said no. They wouldn't because it was too slow and they would lose money using it. Then our manager suggested: "What if you get the same amount of money, no matter what?" Because we had a *very good collaboration with [the construction company] so it could have been arranged, but they were still a bit, argh. So it is really difficult the thing about introducing a new machine.* (Robot maker, WIPER)

This is an empirical finding, but also a methodological challenge. Without the opportunity to see the robot at the test site, we have to rely on the interviews conducted and the analysis of documents, internet resources, and visual imagery to gain an understanding of the robot in its application context. Furthermore, some robots were already being implemented, so we were not observing the development of the robots themselves. The researchers were, however, also able to observe selected affected stakeholders and robot makers at work. These participant observation experiences gave the fieldworkers first-hand knowledge of the affected stakeholders' life-worlds - for example, the difficulties harvesting a particular crop under unpleasant thermal conditions or the difficulties navigating narrow staircases while bearing cleaning equipment in the Portuguese hills. The data generated during observations was recorded in the researchers' field notes. These notes include both analytical and empirical observations – selections the researcher makes from the field, which were selectively included in the Case Write-ups.

5.0 Analytical work and challenges

5.1 Data analysis complexity

The data analysis followed a strict pattern following the 'reeling approach': first each case was written up – and preliminary research findings were identified (for instance in our first case study REGAIN we identified the importance of inclusive design, and in subsequent cases looked for signs of in- and exclusion design problems). Then the interviews were transcribed and placed in an Nvivo database, and we began the hard work of finding patterns across. The conditions of the process of participant recruitment and data collection as well as related challenges inevitably affected the process of data analysis. The following sections discuss it in terms of the main methodological and analytical challenges and related ways to address them.

Big amount of data As discussed elsewhere (Hasse, 2019), conducting 11 cases all over Europe, REELER research searching deliberately for variation resulted in enormous and rich amount of data. In general, due to the emergent character of qualitative research, which does not allow specifying in advance what may be eventually significant, qualitative researchers tend to accumulate large volumes of data. In order to deal with the redundancy in the data, qualitative researchers typically sort the material and identify and focus on the data that contain vital information (Fielding & Lee 1998, 56).

This was also the case of the REELER project where researchers identified and analysed key patterns within and across different cases, with the goal of informing research on ethical robot design, and the REELER Roadmap. The research on ethics and robotics involved an inherent difficulty in identifying responses and phenomena in the field that would be explicitly presented by the study participants as 'unethical'. Thus, the process of identification of the key patterns often required going beyond the semantic content of the data and examining latent themes. Due to the project constraints a large part of data the possible analytical approaches, which did not go across the cases, remained unexplored. For example, with the objective of closing the gap between robot makers and affected stakeholders in mind, from the very beginning the data was analysed jointly for both groups – and only later separated a close-up in analysis. This was also the case with our analysis of female and male participants.

Furthermore, is was a continuous process of back and forth to identify themes across cases – first from the case write-ups and next from our coding. This was also difficult to integrate our ethnographic findings with the innovation economics perspective which is the field of expertise of one of the REELER partners.

The analytical choices we made followed the novel approach of making these ethnographic projects that are normally analysed on a local basis be analysed across cases. Just as in other qualitative studies, the generalisability of the REELER findings can be questioned, despite collecting and analysing a very large amount of data. It is specifically the variation in cases that makes REELER's findings of patterns across cases that strong findings, when we find patterns across. Contrary to other type of methodological interferences that applies case findings to the entire populations, in this case that of robot makers and affected stakeholders, the main emphasis was not on the analytic generalization, i.e. a process of generalising from particulars to broader constructs or theory (Polit & Beck, 2010). It was rather, following the multi-variation approach, to find patterns that open up for new questions about the nature of robot developers and affected stakeholders not previously addressed (Hasse 2019).

5.2 Variation in cases and REELER team

The data collected in the course of the REELER fieldwork was rich not only in terms of quantity but also in terms of variation in terms of the type of robots, participants and nationalities involved (Hasse, 2019). While seeking for variation was an approach deliberately taken in the REELER research, it also posed analytical challenges. In general, there was no straightforward link between the time spent in the field and the amount or type of data obtained. However, having the opportunity to meet a given participant more than once and engage with a company over an extended period of time certainly enriched the case. Also, the very robots selected for the REELER cases significantly varied between each other, from the construction robots, through exo-skeletons to humanoid service robots. Thus, there were significant differences between the cases in terms of the amount and type of data collected. Some of them resulted in a more than the agreed number of interviews and extensive case write-ups (e.g. COBOT or SANDY) while others were relatively limited in terms of the scope and richness of the data (e.g. SPECTRUS or COOP). This was also related to research vs. commercial applications of the robot a given case was built around: In principle, the study of robots that are already available on the market and made public offered much more opportunities to access different sites, participants and materials.

5.3 Data-handling

Across cases, REELER produced 177 interview transcripts from interviews of which 160 participants (engineers, other robot makers and affected stakeholders) went into our joint Nvivo database for further analysis. Audio recordings were made for all interviews. Audio files were transcribed in the original language, translated to English, and anonymized. While the intention was to conduct all interviews in English, we learned in the pilot that this was not always possible nor preferable, because it would exclude certain people from being heard. Therefore, interviews were made in English, Polish, Spanish, Danish, Portuguese, German, and Italian, using interpreters in the field when needed. We decided to use interpreters and translators rather than hiring external fieldworkers, so as to ensure high quality ethnographic work informed by the methodologies and common ground developed by REELER researchers in the first stages of the project.

5.4 Case-write-ups

The Case Write-ups are internal fieldwork documents that detail each case during the fieldwork period. These write-ups are the synthesis of research, raw data, and methodological and analytical reflection for each case. The field notes, images, videos, documents, transcripts, and other data collected during the fieldwork are contained or summarized in the Case Write-ups. These are being used alongside raw data in the analysis process.

Literature reviews and document analysis. The researchers performed database searches and literature reviews to develop a background or history of the application area, robot type, and/or sector. In addition, the researchers produced a history and description of the robot and a network of those involved in its development. This data was generated during initial interviews, through internet research, and through visual media analysis. This information and any images/videos collected are incorporated into the case write-ups. This data informed the fieldworkers' methodological choices in the field and provides context for the analysis.

See Case write-up guide in REELER's Best Practice Research and Observation Guide (*see responsiblerobotics.eu/research/repository*).

5.5 Coding

REELER coded interview transcripts using qualitative data-analysis (QDA) software. This process entailed the initial analysis of Case Write-ups to identify relevant parent codes (key analytical themes). From reading across the Case Write-ups, we formed preliminary hypotheses and develop analytical categories that captured and described some of our emerging findings within the data. We refined, rejected, and created new categories as we pored over raw data, looking for findings both unique to a case, and patterns visible across cases. We did this through critical reading of the case-reports, and through a pilot round of coding our data using the QDA software.

Through ongoing data analysis and methodological reflection, REELER researchers narrowed the analysis from 34 analytical categories to 12 defined analytical concepts. Each of these concepts rested on a hypothesis and guided us in processing our data and in further shaping our analytical gaze in our continued work. These 12 analytical concepts are:

1. Collaborative learning
2. Dehumanization/humanization
3. Design process
4. Education
5. Ethics
6. Ideas and beginnings
7. Imaginaries
8. Inclusion/exclusion
9. Resistance
10. Safety and privacy
11. The distinctly human
12. Work

Researchers then coded the transcripts according to the shared parent codes, suggesting new parent codes or child codes (sub-themes) whenever a new analytical point emerged from the coding process. We processed our raw data with an eye toward these analytical concepts, in a focused coding process through QDA software. However, we also remained open to new concepts that did not fit with existing patterns and coded these in a more open coding process. In the end, we categorized our findings for a more in-depth cross-case analysis.

Multi-variation approach to cross-case analysis.

In our cross-case analyses, researchers systematically combed through coded passages to identify patterns across our 11 cases.

All of the 12 nodes listed above refer to the patterns identified across the REELER cases – and all have led to a thorough analysis presented in our publication *Perspectives on Robots* (*see responsiblerobotics.eu/perspectives-on-robots*). Furthermore, we found one more node of cross-case importance 'gender', which subsequently led to the chapter 'Gender Matters' in this publication.

In our collaborative work on identifying patters across, we first took all the findings 'reeling' out of the 11 case write-ups. Then, following several research seminars we gradually narrowed down our identified 34 nodes (the term for code in Nvivo) down to the 12 listed above – because they showed a persistence through analysis of not just the case-write-ups but also our analysis of the individual interviews. We then coded the whole Nvivo database (of 160 interview – later supplemented with 17 extra interviews) – and read through the whole material to identify the most relevant themes for our final publication Perspectives on Robots. The work on the nodes went into – and are presented as analytical work in each of these chapters.

Chapter 1: Introduction: In the introduction, we find our Human Proximity Model, which is our reading across all cases of how users (affected stakeholders) and robot makers relate to each other. This chapter included all of the findings throughout but had an emphasis on findings tied to node 3+ 6, Design process and Ideas and beginnings.

Chapter 2: Robot Beginnings and *Chapter 3:* Collaboration in the Inner Circle both draw on the same nodes 3 and 6 Design process and Ideas and beginnings but also on node 1 Collaborative Learning.

Chapter 4: Ethics Beyond Safety draw on material from many nodes but especially focus on node 2 Dehumanization/humanization and node 5. Ethics.as well as 10. Safety and privacy and 11. The distinctly human

Chapter 5: Inclusive Design mainly draw on node 8 Inclusion/exclusion

Chapter 6: Innovation Economics draw on the economic research (see below section on economic research) but also on nodes 9 Resistance and 12. Work

Chapter 7: Learning in Practice build on ethnography from the case write-ups and node 4. Education.

Chapter 8: Imaginaries build on node 7 Imaginaries.

Chapter 9: Economics of Robotization draw on the economic research (see below section on economic research) but also on nodes 9 Resistance and 12. Work

Chapter 10: Meaningful Work draw on nodes 9 Resistance and 12. Work

Chapter 11: Gender Matters build on subsequent analytical work throughout the database

Chapter 12: Human Proximity build on analytical work throughout the database but also on node 1 Collaborative Learning

Chapter 13: Conclusion build on analytical work throughout the database

Each node could be drawn out of Nvivo as a 'query' consisting sometimes of many hundreds of pages of quotes, which were then connected with field reports and visual material etc.

In general, we worked in the 'reeling' manner. As an example, we can take the first identified node 'Inclusion/exclusion). It was found to be of interest in the very first case write-up as well as throughout all case write-ups – and thus became a node through which we looked for in- and exclusions through the database material.

The node identifies how robot developers overlook the diverse body sizes of both end-users, and directly affected stakeholders in robot design. This for instance entailed creating control systems that could only be used by people (often men) with very large hands. From our analysis of the node and case write-ups, we found new examples of how robot developers inadvertently excluded people who differed from their normative understanding of not just bodies, but also cognitive skills and physical environments. We also early on identified 'imaginaries' as an important node to work on throughout the material, as almost all robot cases showed their robots as more well-functioning and autonomous than what was found when the robots left the laboratories and were used in practices. 'Collaborative learning' was embedded in REELERs project design – and our analysis across case led us to suggest the two-pronged strategy presented in Perspectives on Robots: a more holistic engineering ethics, and a new education of alignment experts.

REELER analysis seminars. The patterns identified in our cross-case analyses were discussed and dissected in a series of analysis seminars. Returning to the shared theoretical perspectives developed in the early stages of the project, REELER researchers focused findings in Analysis Reports. These reports were the problem formulation for the REELER Roadmap, and were the basis for the publication *Perspectives on Robots,* and the resulting recommendations for public policy.

5.6 Methodological challenges

Just as is it difficult explicitly to define ethics, it is even more challenging to study it through ethnographic research. Given its focus on the totality of human experience and embedment of ethics in socio-cultural contexts and everyday life practices, it may be difficult to clearly articulate and grasp the underlying ethical principles and norms, both for the study participants and researchers. Part of the difficulty is also in the people's tendency to present themselves as 'ethical', be it to the public or in their own eyes, particularly if it involves robotic companies and research laboratories that often benefit from public funding and count on the consumers' acceptance of the products and services they offer. This required REELER researchers to largely 'read between the lines' when conducting empirical research on ethics and construct the findings based on the observation and engagement with a given social and material reality as a whole rather than only the data collected through interviews. At the same time, interviews remained the key source of data that were later critically analysed within the REELER ethical robot design and responsible robotics frameworks. Also, in REELER, in addition to ethics being a subject that inherently defies scientific investigations (Wittgenstein, 1965), the challenge was also in engaging with the empirical study of ethics and robotics as an international and interdisciplinary team and within the collaborative learning frameworks. While collecting the data and analyzing them as part of isolated efforts is a relatively standard process, integrating the data and related analysis in line with the collaborative learning approach requires specific long-term engagement of the entire team with no guarantee of success.

The following sections discuss different methodological challenges posed by the REELER fieldwork (for a detailed discussion of the REELER conceptual and methodological frameworks as well as related analysis of the ethnographic fieldwork (*see Hasse 2019; Hasse, Trentemøller, & Sorenson 2019*). The aim of the discussion is as much to inform analytical findings and outcomes of the REELER project as to engage in a self-reflective process that would help further refining interdisciplinary research collaborations in the area of ethics and robotics.

In general, field research always presents significant complexities and challenges, to the point that Human-Robot Interaction research on people and robots outside the laboratory has often been described as research 'in the wild' (Šabanović *et al.,* 2006)). While to some extent the challenges discussed below can emerge in any ethnographic research, the main focus here is on the specific requirements and conditions found in the process of the REELER fieldwork.

5.6.1 Limited contact information

From the start, there was difficulty identifying contact information that would allow communicating directly with persons seen as suitable candidates for the study in the role of robot makers. While university research laboratories typically make staff profiles and contact e-mails available on the relevant websites, private companies tend to be very protective of their staff contact information and leave the opportunity to contact the company only via a general phone number, e-mail address or inquiry form (the situation that varies between the companies and countries). As often argued, this is not just to protect technical secrets, but we found it was also very much a question of a need to control a public image.

This is why, in order to get access to key participants such as CEOs, managers or lead robot developers among others, REELER researchers often needed to rely on the contact facilitated by third persons, e.g. secretaries or customer service staff – a strategy that may or may not work. An alternative approach included getting in touch with relevant persons for example during industry fairs, exhibitions or via networks of persons collaborating with a REELER team in different forms, including with the use of snowball sampling (a technique that implies identifying and recruiting study participants with the assistance of other participants who recommend and facilitate contact with other participants). While privacy concerns are of course a valid argument in restricting the availability of the contact data, it can be also seen as a way to reinforce 'a robotic bubble' (whether deliberately or not) that remains open to only some actors and affected stakeholders. In order to increase the chances of reaching a variety of participants, it required a high degree of flexibility and creativity on the REELER researchers' side (e.g. one of the participants, a pilot, was identified and approached on a shuttle bus at the airport; also, efforts were made to recruit warehouse workers via one of the community and advertisement websites).

5.6.2 Underrepresentation due to supervisors' control

In general, when identifying and involving people in a REELER study, attempts were made to cover a large variety of robot makers and affected stakeholders. Some groups, however, remained underrepresented. When analysed from the perspective of recruitment strategies, to a large extent underrepresentation of persons or perspectives was due to the control exercised by supervisors (of course, gender imbalance is also part of the underrepresentation subject, however it is the topic of another chapter (*see responsiblerobotics.eu/chapter-11*). In other words, when approaching both potential robot makers and affected stakeholders, the difficulty was also not so much in finding contact information (the latter was either already accessible or, on the contrary, it was in principle not meant to be public, e.g. phone numbers of warehouse workers) as in obtaining permission of the relevant supervisors. On several occasions, there was a mismatch between the employees' willingness to participate versus a lack of approval of their supervisors. As illustrated by quotes below, while an employee in question first expressed his interest in participating in the study, he or she later withdrew from the study due to the decision made by a person in charge of decision-making. A lack of supervisor' approval was potentially due to different reasons, above all a preference to dedicate employees' time and efforts to the tasks seen as more relevant for the company (see below).

EXAMPLE 1: *No problem at all, I am happy to help. Provided anonymity is provided as our company is highly data sensitive, I will be able to talk.*
(Supermarket chain, Project Manager, Affected Stakeholder; e-mail communication, 10 April 2018)

Bad news I'm afraid. I have been asked to withdraw from this study after enquiring about information from warehouse staff. Company policy will not allow for this. In an unofficial capacity, I can answer any questions via email if this helps at all.
(Supermarket chain, Project Manager, Affected Stakeholder; e-mail communication, 25 April 2018)

EXAMPLE 2: *Sorry for the delay in reply, I had not forgotten but currently waiting feedback from the sales director on this matter. I will remind them and let you know as promptly as possible.*
(Automation company, Sales Engineer, Robot maker; e-mail communication, 13 March 2018)

Sorry for the delay in reply, this was with good reason as I had hoped to convince our senior management team to assist in the report. Unfortunately, the directors have decided not to participate and so I must decline your interesting offer to join the Invitation to the EU project on Robots and Ethics report.
(Automation company, Sales Engineer, Robot maker; e-mail communication, 27 March 2018)

EXAMPLE 3: *Thanks for the invitation to the EU research project on roboethics. This is very important to us as we are working within UK and Europe and ISO for this.*
(Robotic company, Project Coordinator, Robot maker; e-mail communication, 13 November 2017)

We won't be able to participate because our Technical Director decided so.
(Robotic company, Project Coordinator, Robot maker; paraphrased phone conversation, 15 January 2018)

In general, one of the most difficult groups to access were robot operators (workers), both low-skilled and high-skilled. Across different sectors, operators are generally 'controlled' by supervisors. For example, three interviews with operators took place in the presence of their supervisors with the excuse of sharing the same office space (or in the case of COOP, the need to translate operators' words into English), namely at the test warehouse (WAREHOUSE), manufacturing facility (COOP) and in the case related to track inspection robots (OTTO). The latter also involved interviewing the robot company employees in the presence of their supervisor, despite the explicit kind request made by a fieldworker to consider leaving. Not surprisingly, children who took part in the study (ATOM) were also interviewed in the presence of a teacher or a supervisor. Engaging in a conversation in the presence of the supervisor (and of a researcher herself for that matter) certainly influenced the operators' responses. Such impact, however was not always and not necessarily negative and it varied from case to case (the exact nature of the professional relationship between a supervisor and operator in question was not assessed). The influence of supervisors could also be observed indirectly in the attitudes demonstrated by the operators towards robotization. For example, when asked about his willingness to potentially try a robot at work, a warehouse worker said he would be interested to do it by *'it is down to the boss really'* whether to try robots or not. Moreover, a limited access to different participants due to their lack of decisional power well-illustrates the situation where the entire field of roboethics and responsible robotics is brought forward by only a small group of individuals coming from academia, industry or public institutions. In other words, due to their professional and social roles, only selected persons typically participate in and inform works of different committees, organisations and initiatives that aim to develop guidelines for ethical robot design for society as a whole (in this sense, the REELER project is no exception). In any case, while ensuring sufficient representation was not possible across all of the REELER cases, some of them did extensively involve and give voice to groups that are typically viewed as underrepresented such as cleaners (SPECTRUS) or mechanics (HERBIE).

5.6.3 Limited access to robots at work

Most of the interviews were conducted at the offices or what was viewed as a workspace. Several persons were interviewed via Skype. Only some participants offered a tour around the company facilities and provided an overall overview of the projects and activities in which the given company or laboratory is involved. While this also included showing robots that a given case was focused on, the availability of robots was often limited to single and short demonstrations, and typically in highly controlled settings rather than real-life situations. This was the case for example of a warehouse robot or track inspection robot where the demonstrations were executed by robot makers themselves or persons classified as both robot makers & affected stakeholders rather than direct end-users (an exception of that rule was for example a rehabilitation robot). In some cases, demonstrations were limited to only static conditions (e.g. COOP: light manufacturing robot) or demos delivered during public events rather than in dedicated environments (e.g. ATOM: educational social robot), or it did not take place at all (e.g. WIPER: construction robot). To some extent, this was due to only limited presence of robots in the market, especially if it includes new types of service robots (e.g. in the BUDDY case) or early stages of robot development (e.g. in the SANDY case). A different factor was also time constraints that often did not allow affected stakeholders to engage in long-term study participation and site visits that would offer proper 'hands-on-experience' to REELER researchers in relation to robots. One could argue, however that limited access to the actual robots at work was also due to the strict control exercised by robot makers over their creations. The latter applies not only to the frequently idealized image of robots developed in the mass media but also other forms of making robot makers' work accessible to the public such as REELER research.

5.6.4 Time constraints

If providing reasons for not to get involved in the REELER study, different persons pointed to time constraints and related *'pressures of work'*. This was particularly the case of the robotic companies, including start-ups. In some cases, time constraints seriously affected the entire recruitment process as it took months to select a suitable date for the study. For example, one of the participants in the WAREHOUSE case repeatedly argued he was *'terribly busy'*, or *'completely underwater'* and *'it is absolutely crazy times for the whole company'*. Some companies explicitly set the limit for the duration of the interviews and visits, including because of the CEO's decision who is *'very protective of our developers' time'.* For example, one robotic start-up in the WAREHOUSE case agreed to only a 3-hour long visit. Other robotic company involved in the BUDDY case allowed for a meeting that would take no more than one day and the interviews that would last no longer than 30 minutes. The need to keep employees focused on the tasks relevant for the company in question rather than assist in the interviews was also why a REELER researcher was not granted permission to attend a robot competition organised by the company with the use of its robots (the tournament was closed and limited to the robot teams only). The only permission granted was to attend a related press conference which included a short visit to the competition space. Even in such a case, the researcher was asked to strictly refrain from communicating with the company employees, which would interrupt their work. Thus, time constraints was the reality faced across all the REELER cases to a varying degree where most of the visits were limited to only a few hours or days, and with some exceptions, the duration of the interviews was also reduced on average to 1,5 hour. In some cases, when interviewing participants at their workplace, they were repeatedly interrupted by other colleagues, phone calls and tasks waiting to be completed. Also, limited time resources applied to the REELER team itself, as several cases needed to be conducted in parallel and by single fieldworkers. This of course made it difficult to fully explore all the REELER cases and collect the amount and type of data that would normally be available if proper relationships with the study participants were developed and long-term presence of researchers in the field allowed. One of the main ways to deal with time constraints was to tailor each interview scenario and each visit to a particular case and participants (e.g. by excluding the video part from the interview or adding new topics) to fully explore the issues considered as essential for addressing ethical robot design and helping closing the gap between the robot makers' visions and societal concerns and needs.

5.6.5 Other priorities and profit-oriented approach

In addition to quoting time constraints as a reason for rejecting the invitation to take part in the REELER study, and somehow in relation to it, several persons contacted as potential participants claimed they were not in a position to discuss ethics as it was not related to the type of work and activities they were part of. The very lack of any response, which was relatively common, also illustrates a lack of interest in ethics and robotics. While this came as no surprise when it comes to engineers who often take a disciplinary view on ethics, it was not entirely clear why such organisations as for example some trade unions viewed a discussion of ethical challenges related to robotics technologies as not sufficiently relevant. For example, when explicitly asked about general reluctance of trade unions towards participating in the REELER study, a trade union representative replied that *'you academics and your research are a way, way far from our top priorities'* (phone conversation; paraphrased, WAREHOUSE case). Some of the companies explicitly asked about the potential benefits such as for example helping to advertise and promote the company. The company in question, which was part of the WAREHOUSE case, also pointed to the lack of financial reward related to the participation in the REELER research: Because of the pressure from investors and clients the company needed to *'stay laser focused'* on its key priorities where *'CEO banned all non-revenue generating or customer focused activities'* (e-mail correspondence, WAREHOUSE case). According to another company, *'a lot of interview to different people at our company could be very expensive for us'* (e-mail correspondence, BUDDY case). In the ATOM case, when asked why did the start-up in question accept the invitation to the REELER study, one of its founders said it was because *'you never know when this type of contacts can turn to be useful'*, e.g. in terms of collaboration within EU-funded projects (conversation paraphrased). In this sense, contributing to the European research and frameworks for ethical robot design was sometimes seen as insufficient argument to get involved in the REELER study. This raises ethical concerns, particularly if a company or organisation in question benefits from the European funding. It also poses serious challenges to the very idea of pursuing ethical robot design and 'culture of responsible robotics' in Europe. At the same time, it is important to note that an instrumental and profit-oriented approach was not the only approach observed and after all over 160 persons did participate in the REELER study. For example, the use of a snowball sampling technique involved making efforts to select the study participants with the help of other participants on a voluntary basis and without any immediate or obvious benefit for the study participants who were helping in the recruitment process. The fact that some participants expressed genuine interest in knowing more about ethics and robotics as well as creating relevant collaborative networks is very promising.

5.6.6 Confidentiality concerns

The need to protect confidentiality and ensure anonymity of the study participants and their work constituted a challenge per se. From the perspective of access and recruitment strategies, it is important to note that it occasionally required finding a delicate balance between addressing the objectives of the REELER research and obtaining necessary data, and at the same time meeting confidentiality requirements. For example, as far as highly confidential projects were concerned (COOP in particular), when recruiting participants other than the main robotic company involved in the study, it involved introducing the project and purposes of the interview without ever making any reference to the company in question or the robots it produces that were subject of that particular REELER case. This was also the approach needed when conducting interviews that included indirect ways of discussing the type of robots and industry in question. Such an approach posed a risk of involving the persons and asking the questions that were not entirely relevant for the case in question, the risk that was mitigated by being aware of its existence in the first place. In addition, due to confidentiality concerns, there were significant differences between the study participants in terms of their openness to discussion of different matters. For example, some of the participants refrained from discussing certain subjects or asked to remove parts of the material from the interviews and the transcripts that followed. Others initially expressed serious concerns related to confidentiality but later demonstrated highly collaborative and open approaches (it would be interesting to investigate whether the degree of openness towards REELER researchers was also symptomatic of the degree and quality of collaborations with actors/affected stakeholders outside of a given company or organisation). As mentioned above, investigating the subject of ethics where in principle none of the individual or institutional participants is willing to openly admit their approaches or conduct may be potentially unethical requires 'reading between the lines'. In order to successfully deal with confidentiality constraints, it also required taking a similar approach and address different subjects in indirect and creative ways.

5.6.7 Language barrier

While this was not a main challenge, one of the obstacles faced in the course of the REELER fieldwork was a language barrier. In general, the proportion of native English speakers among the REELER study participants was relatively low. Most of the participants were able to speak fluent English indeed. Occasionally, interviews were conducted with the help of interpreters, e.g. in the SANDY or SWEEPER case. In some cases, it were fieldworkers themselves who were able to conduct interviews in the participants' mother tongues and later translate them into English (with or without the support of professional transcribers), e.g. in WIPER, ATOM or OTTO cases. In other cases, REELER fieldworkers simplified the language of the interviews to accommodate the participants' language competencies. On several occasions, however language barrier was serious enough to entirely hinder participation in the REELER study. For example, one of the participants in the COOP case explicitly recommended conducting interviews in a native language as many of the trade union members in question could not speak English (in fact, this was also the REELER case where an operator who took part in an interview, needed an interpreter). The fact that none of the trade unions express interest in the study, despite the possibility of providing an interpreter, was most likely related to a language barrier, (a similar situation was observed in the HERBIE case with a potential participant coming from outside of Europe). Some of the persons who were contacted on the phone in an attempt to invite them to the study; however, they were not able to engage in any conversation in English. Others struggled to clearly express themselves in English (e.g. agricultural workers in the SANDY case) and occasionally used expressions in their native languages (e.g. in the OTTO case). All in all, the dominance of English language is a known issue in research and science and particularly problematic in such heterogeneous cultural contexts as Europe. Also, one needs to remember that even if conducted in the languages other than English, the very act of translation may present new complexities as it goes far beyond a merely technical task (Marshall & Rossman, 2016). Thus, the approach followed in the REELER fieldwork was to choose the language that would allow including possibly a variety of the study participants within the existing constraints.

5.6.8 Non-disclosure

As already mentioned many few companies that took part in the REELER study (also the public actors), required signing a Non-Disclosure Agreement (NDA). Those that did not involve signing NDAs were nevertheless often regarded as also highly confidential, i.e. COOP. On one occasion in the WIPER case, the invitation to establish contacts and visit one of the big technological companies was rejected due to the excessive time and work needed to sign NDA among others. As discussed below, confidentiality concerns influenced modes of data collection and analysis, particularly the type of material that could be shown, recorded and discussed.

5.6.9 Restrictions on data collection

Whether an NDA was signed or not, different companies demonstrated varying levels of confidentiality concerns. On the one hand, some of the participants remained cautious to discuss certain subjects or explicitly requested excluding certain references to the company and its work from the data collected (e.g. this applied to a large part of recordings made during a site visit at the manufacturing site in the COOP case). One of the companies also posed strict restrictions on who to contact for further interviews among its collaborators. Across different REELER cases, there were also restrictions on the possibility to take photographs or video recordings of the sites or their parts, particularly among robot maker participants. One could argue the main reason for confidentiality concerns was the need to protect a competitive value of the company or laboratory's work, especially in the case of the manufacturer involved in the COOP case. However, knowing we were social scientists it seems unlikely 'technical secrets' was the main concern. Occasionally, it seemed that taking a cautious approach, close to mistrust, was due to the very subject of the REELER study (ethics) that potentially could put the company or an individual in a bad light. On the other hand, even with NDA signed, a robotic start-up in the ATOM case demonstrated a highly open and collaborative approach in the course of the fieldwork and did not pose any restrictions concerning data collection and analysis. On a few occasions, the companies would have even liked to gain visibility through the participation in the REELER study (especially those whose robots were meant to be commercial products), an expectation that the REELER team could not meet. Thus, dealing with confidentiality concerns in the course of fieldwork required REELER researcher to negotiate conditions with the study participants as well as remain fully transparent about the goals and procedures followed within the REELER project.

5.6.10 Restricted access to the sites

In some cases, particularly if it involved big manufacturing companies (e.g. COOP) or innovative start-ups (e.g. HERBIE), access to the company's offices and facilities was highly restricted. This was probably not only due to confidentiality but also security reasons. Fieldworkers could still access the sites in question but only after obtaining a formal approval and in the presence of the company's representative. Even in less formalised structures such as for example in technological parks (WAREHOUSE) or schools (ATOM), it was always necessary to have a contact person who would later assist the REELER researcher during the visit. This posed limits on the types of observations fieldworkers could engage with and the type of material they could gather. In some cases, the access to the participants' workspace was denied, namely when meeting air traffic controllers (the meetings took place in the offices outside of the air traffic control towers and in a café). This may also be why a pilot participant invited the fieldworker to conduct an interview at her home.

5.6.11 Restrictions on the use of data

Across different REELER cases, one of the biggest challenges was to understand how to tackle visual material. First, it was, as mentioned, not always possible to display the videos of the robot a given case was built around, as expected in the interview scenario. This applies to both public material of the case robot and real-life visual materials gathered during the fieldwork. Since videos were generally used to elicit reflection on a given topic, if no videos could be displayed, other methods of inspiring reflection were used in the course of the conversation. While only a few companies explicitly requested fieldworkers to refrain from taking photographs or video recordings during site visits (e.g. in the COOP case), even if fieldworkers did collect visual materials, they could not use them in the following stage of data analysis in terms of publishing such materials (otherwise the participants' anonymity would obviously be compromised). In some cases, when taking photographs was not allowed, an alternative solution was to study the relevant materials available online or on the site (e.g. brochures), if possible. At times, this led to paradoxes where, on the one hand, the robot in question was already made public and publicised through different mass media (some companies even shared additional materials, like PowerPoint presentations) about the company with the fieldworkers. On the hand, it was not possible for the project to use such materials or any other visual data collected in the course of fieldwork regarding the company and its work. Some of the participants heavily censored the interview transcripts sent for their approval and in one case did not approve the transcript at all, due to what they saw as an insufficient degree of anonymization of the transcript (a robotic company in the WAREHOUSE case). The solution was to incorporate visual materials and removed parts of transcripts to the process of data analysis but exclude them from any project publications.

5.6.12 Anonymization constraints

One of the biggest challenges in the REELER project was the need to ensure anonymity of the study participants. This was particularly for the stage of data analysis, as the difficulty is not so much in anonymising data as discussing them in the anonymised form in public. For example, how to discuss a given case in a way that would inform our understanding of the European robotics and ethics without ever mentioning a particular robot, country and in some cases the entire sector the case was built around? Working on the semi-anonymised data when coding it also posed some difficulties as it occasionally made it difficult for the REELER team to follow all the changes made and acronyms used throughout the entire body of data. This was in the situation where different cases required a different degree of confidentiality and some materials could be used for the purposes of the internal analysis (especially video materials) but not as part of publications and dissemination activities. As a result, the REELER team made efforts to come up with creative ways to deal with the confidentiality and anonymization constraints, from the way the fieldwork was conducted (e.g. by building a case around more than a single robot that otherwise could be easily identifiable) to the way the data was described (e.g. by referring to adjacent notions and sectors and building a narrative around them).

5.6.13 Coordinator's predicaments

It is clear that in a big and innovative project like REELER is not easy to coordinate. It was a specific wish in this project that the partners actually worked together across disciplines and various motives and interests in participating in the project. In terms of data collection, it was a problem, but also enriched the project, that we worked with so many different researchers. More than 40 persons have been involved over the projects lifetime. This also meant that some of our work, especially in data analysis and the multi-variation approach, was not clearly understood by all – almost till the very end of the project where the analytical result were written up. Some problems emerged already as we did our fieldwork, as some researchers had problems identifying robot makers – and especially finding affected stakeholders not tied to the actual robot lab. However, these problems were in themselves fruitful and led to good new discussions of the different types of stakeholders.

The main difficulty here actually turned out to be in data analysis. It is challenging to come up with a coding and analysis approach that allows integrating a large amount of data which varies in subject and scope, while finding patterns common for all, or most of the cases. On top of that, this analytical work was coordinated between many different researchers who, more or less, understand the empirical data they analysed and the scope of the project. Since the data was coded by multiple REELER researchers located in different countries and at different times, the coding process and the analysis that followed needed to be agreed upon, coordinated and shared within the entire team (to the point of ensuring that all coders use the same or compatible version of the NVivo coding software). What adds to the complexity is the fact that some REELER partners were not involved in the coding process but they were involved in the discussion of the coding outcomes. Given the interdisciplinary character of the REELER team, a large part of analytical work included developing a common understanding of the terms and notions used in the process of analysis and in delivering specific project outcomes such as this publication, *Perspectives on Robots*. Thus, the challenge was both technical and analytical in nature. All in all, as an ongoing process, the analytical stage of the project has led to meaningful results, both in terms of research findings and dissemination activities.

6.0 Economic research

REELER's economic research goes beyond traditional theoretical economics based on mathematical models to a practical social science using data to test claims and explore phenomena. REELER's researchers have combined economic data with modelling and data visualization to explore research and development processes and the effects of robotization.

1. *Economic analysis of R&D* Several sources of empirical data have been used to get an impression of where robot development activities take place, who is conducting robot research & development, how much and who is collaborating therein, etc.
2. *Agent-based modelling* Computer models of interaction have been used to explore robot design processes that produce a technically feasible robot that meets market demand, and to study the impact of robotization on employment and wages of workers and the effects of policy interventions such as robot tax and universal basic income.

6.1 Using economic data on research & development activities in robotics

The last couple of decades, the field of economics is changing from a mostly theoretical discipline hinging largely on mathematical models into a social science using data to test claims, explore phenomena, etc. In the REELER project, several sources of empirical data have been used to get an impression of where robot development activities take place, who is conducting robot research & development, how much and who is collaborating therein, etc.

Within REELER a variety of empirical research has been conducted (see Table 1), mostly in the setting of MSc theses advised by Ben Vermeulen, supervised by Andreas Pyka. The data is extracted and processed using University of Hohenheim proprietary tools developed by Ben Vermeulen.

Topic	Principal investigator	Data used
Occupational, taxonomic perspective of structural change due to robotization + estimation of susceptibility to robotization across a range of occupations	Jan Kesselhut	Bureau of Labor Statistics North-American Industry Classification Atlas of emerging jobs
Robotic technological profiles of EU countries	Erica Spinoni	EPO RegPat, EPO PatStat data Concordance table IPC -> NACE2
SWOT analysis of robotics innovation systems of Italy and Germany	Ashok D'Anella Bhatia	Various Eurostat set CORDIS public research funding
Regional predictors for robotic public research funding	Farid Kamranzade	Regional Innovation Scoreboard CORDIS public research funding Various Eurostat set
Regional & innovation system determinants of AI research & development activities; (descriptive statistics, principle component analysis & regression analysis)	Klodjana Doci	ORBIS data on entrepreneurial activity CORDIS data on public research Scraped WIPO trademark/ brand data, matched with EU-IPO data for location, representative, etc Extensive use of Eurostat data
Impact of robotization on agricultural sector across the EU	Melina Foka	Extensive use of Eurostat data

Table 1. Research topics, investigator, and data used in REELER's empirical research on the robotics research & development activities and innovation systems in the EU at regional or country level. All projects have used data extracted, processed, and provided using tools developed by Ben Vermeulen.

Obviously, the findings contained in these theses cannot be summed in a few paragraphs. However, there are a few clear findings on the robotics research & development activities in the EU. A common finding is that there is a strong correlation of existing (i) innovation systemic factors (research institutes, knowledge institutes, etc.), (ii) technological (knowledge) infrastructure (people with tertiary education, broadband adoption rate, etc.), and (entrepreneurial) firm presence with the ability to secure public funding as well as realize innovative output (proxied as patents). Moreover, this is so even when controlled for general research activity, population density, general innovative output, etc. As such, the robotics sector is apparently characterized by (1) economic externalities reaped by clustering of companies and institutes with specific technological capabilities and knowledge and/or or (2) localized spin-off dynamics. Given the agglomerative forces thus at work, it is not surprising that there are only a few hotspots in Europe. That said, interestingly, it has been shown that there are countries 'specialized' in certain types of robots, often backed by a technologically specialized innovation system. For instance, in The Netherlands, there is specialization in agricultural robots, arguably due to a 'cluster' of entrepreneurial firms and prominent presence of research institutes. Moreover, Italy has shown a proficient scientific research infrastructure and the north notably in medical science. Robotics research & development culminated around medical research. Similarly, given the ties of robotization with car manufacturing and the long-standing tradition in that field in (mostly the south of) Germany, there is agglomeration of industrial robot development there, for which less basic science but rather more applied science institutes are involved. That said, given that economic development paths generally sees labor mobility from agriculture to industry and then to services, and most countries (including the new accession states in Central and Eastern European countries) feature industrial robot research & development activities. After all, manufacturing firms need to rationalize production to be either globally competitive and prevent import substituting local production.

The economics of this clustering of specialized robot research & development is that, either the sector of application is rationalizing production thus constituting a strong demand pull effect, or that, there is fundamental scientific research stimulating spinoff dynamics in application using advanced technologies such as robotics thus constituting a strong science push effect.

Do note that (public) research projects and innovation networks do contain actors from across the globe (Europe). Generally, this is based on expertise and capabilities with particular specialized robot components (e.g. gripper or vision technology) possible due to an extensive modularization of robot designs. However, arguably, this spatial span is also driven by (informal) requirements of the funding agencies with the intention to establish knowledge transfer and cross-fertilization.

REELER thus established a foundation for further economic empirical research and several of these works are currently finding their way to scientific publications.

6.2 Using agent-based modelling and policy laboratory for 'what-if' analysis

An agent-based model is a computer model of interaction of agents (e.g. individual humans, companies, prey and predator animals) using computer simulation in a dedicated software package (e.g. NetLogo) or in general-purpose programming languages (e.g. C#, Java). In such a model, each agent is implemented as a set of resources (e.g. money, energy, knowledge), goals (e.g. create new knowledge, sustain certain level of energy), and routines to attain those goals using the resources. Moreover, the agent has routines to (i) perceive its surroundings (e.g. nearby agents, nearby opportunities) to constructs its particular worldview and its own position in it, (ii) decide on executing actions upon own resources, the world around it, or its location therein, to fulfil particular (sub) goals. Agents may also enter and exit the simulation based on certain criteria (e.g. perish when out of energy, go bankrupt). Agent-based modeling is used for a rich variety of topics, e.g. spreading of diseases, research collaboration, population dynamics in ecosystems, spatial competition of firms, development of housing prices, etc.

On top of these agent-specific routines, there are routines that operate upon the 'world', both with a conceptual purpose (e.g. a disaster may occur in the simulated world), or to obtain research data on the development of certain variables. Indeed, the researcher can transparently and unobtrusively monitor the development of resources, locations, actions, etc. over time. The researcher can also run simulations repeatedly, and, as such, for example, vary parameters and study simulated development of variables of interest ('Monte Carlo' study). This allows conducting 'what-if' analysis in general, and in economic models construct a so-called 'policy laboratory' in which the researcher can study the impact of interventions on the (development of the) simulated word. Agent-based models allow for ill-defined or limited agent routines: agents simply execute actions whenever certain (ill-defined) conditions are met. As such, the researcher can even experimentally vary these routines. In fact, the researcher may determine routines (for certain actions, regarding certain goals, or given certain conditions) that give rise to particular outcomes. This 'abduction' is a third way of doing science, next to induction and deduction.

In the REELER project, two ABMs have been developed. One ABM to investigate which "robot design roadmap" for robot developers produces a technically feasible robot design meeting market demand. The second ABM is designed to study the impact of robotization on employment and wages of workers and the effects of policy interventions such as robot tax and universal basic income. The methodological considerations for each are discussed in more detail below.

6.3 Agent-based model of robot makers competing with robot design roadmaps

In the first agent-based model, we sought to determine a "robot design roadmap" for robot makers to follow that is most likely (among a range of alternatives) to produce a technically feasible and market viable robot. This first research line proved highly experimental and after analysis of the ethnographic data to be used,

The original objective was to develop an agent-based model to validate and systematically study effects of collaborative learning and design routines used by robot designers and users as found in WP3 and WP4 in relation to robot design expectations and specifications vs. user acceptance rate. Yet, this attempt to mix methods proved too challenging, as the nature of the qualitative, ethnographic interview, narratives could not be sufficiently quantified to be applied in a pure agent-based model. There were two main reasons for this. Firstly, although the ethnographic interviews did include questions on the design process, the interviews provided sparse information on the actual timing for design decisions let alone which stakeholders were involved, what were the considerations for various design options, what was the status quo of market information at the time, and what ultimately led to the design decision made, etc. In retrospect, the fact that such 'shortcomings' occur is in line with various cognitive scientific theories that are in effect when reporting in interviews notably on complex subject matters in a (possibly far) past. To name a few: people have difficulty recollecting actual sources of information, orderly reporting complex interactions, engage in selective abstraction/ overgeneralization/ magnification, etc. Moreover, and this is to be regarded as conceptual result of the REELER research corroborating innovation economic theory: it was observed that the actual development decisions are taken much more distributed and decentralized than envisaged (e.g. in part in previous projects even), so interviewees are only able to reveal parts of the design process (and a subjective interpretation at that). Secondly, despite the structured appearance of new product development methodologies, the actual research, development, and design process in practice has been found to be messy, iterative, recursive, and highly interactive. Therefore, for a proper conceptual grasp and operationalization for agent-based modeling, an extensive socio-technometric analysis of the design process would be required.

As such, it is very challenging to devise agent heuristics that reliably mimic real-world design decisions, let alone properly emulate the real-world design process. Given the broad scope of REELER cases, we would probably only be able to cover a single case, decisions would become highly deterministic, and the ABM results would be particular for that single case and with limited external validity. (Moreover, it would become a so-called 'history-friendly model', which is not without controversies in the ABM community).

However, the ethnographic data did give the valuable insight that the robot design process is involved, recursive, and reiterative. Arguably, firstly, real-world robot makers have to cope with 'real uncertainty' about what customers want, which technology is available (or can be discovered), and how and in which combinations these technical modules need to be put together. New insights may thus force robot makers to restart parts of the design process. Secondly, robot makers suffer 'bounded rationality' and as such do not know exactly which sequence of market and technological research steps are to be executed, but rather do so experimentally and by imitation of successful peers.

Consequently, the routines ('heuristics') followed by the robot-developing agents are to be grafted in what is called 'bounded rationality' in behavioral economics. Moreover, the design problem these agents face is to feature 'technological complexity' with uncertainty in discovery of new components and about technical feasibility of combinations, etc. Finally, the uncertainty about what customers want. Given that the ethnographic research cannot provide concrete operational definitions of agents' behavior and there is this fundamental uncertainty inherent to technological and product-market innovation, conducting a systematic Monte Carlo study for a variety of parameter settings to 'optimize' the roadmap is non-sensical. Instead, we sought to mimic real-world emergence of product design roadmaps for highly stylized, low-level technology and market research activities.

This also reflects the fact that also the 'new product development' methodology was proposed and gradually developed over the course of several decades; in the past companies followed a 'pure engineering' perspective simply building what engineers deem best, while nowadays companies seek to discover what customers want, pick profitable market niches to target, and involve customers in the design decisions. However, while more respectful of the consumers and catering to their needs, it is by no means obvious that such a 'demand pull' approach is always best. For instance, customers may not know what they want until you show them prototypes, thus effectively stalling development. Or, product performance may become clear only when used in practice. Consequently, we sought to allow for the "emergence" of product design roadmaps in a variety of market and technology structures. To this end, we simply implemented competition of agents following *different* design roadmaps, followed by imitation of relatively successful roadmaps by other agents, see Figure for an insight in the 'evolutionary' process.

A particular challenge in the 'operational implementation' of this model is the fact that a robot is a purposeful construction of various technical modules, whereby the robot-designer-agent has to discover both the modules as well as the structure by which they need to be combined. Operationally, robots were perceived and codified as a directed graph of modules, whereby there is a 'universe' of such graphs but only a few are technically feasible, and only a few ultimately meet requirements of consumers on the market ('desirability').

This basic agent-based model on 'evolutionary superior' product design roadmaps revealed that there is some universal structure in the design roadmap, but under rather

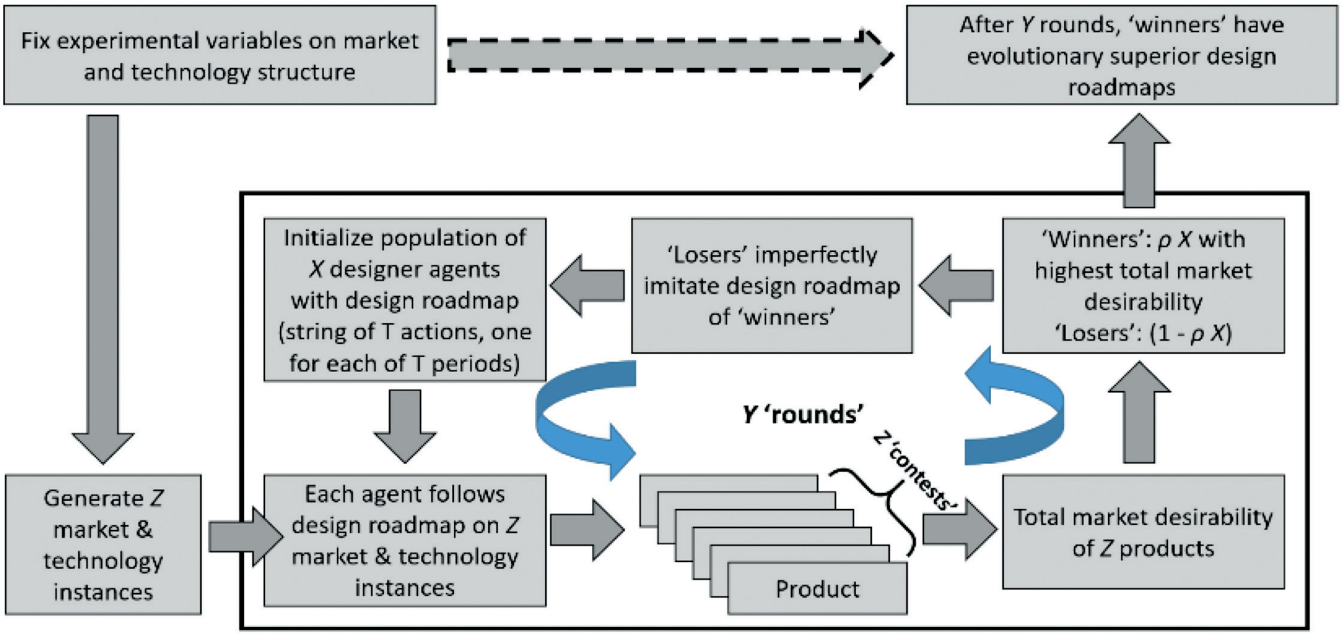

Figure 6. Schematic representation of the ABM with agents competing with 'design roadmaps' in Z 'contests', After Y rounds of contests in which agents may (imperfectly!) imitate superior roadmaps, there is an evolutionary superior design roadmap.

strict assumptions. So, to arrive at generalizable results with prescriptive value for real-world robot developers, rather than 'emulating' specific design processes with strong assumptions about human design decisions, the focus was shifted to actually studying the decision heuristics that humans use when coping with an 'involved' design process. This is described in detail later.

Output of the experiments 1-3 is contained in several publications / conference proceedings:

– Vermeulen, B., Chie, B.-T., Chen, S.-H., Pyka, A. (2017). "Evolutionary programming of product design policies. An agent-based model study.", Proceedings of the 21st Asia Pacific Symposium on Intelligent and Evolutionary Systems, pp.1–6.

6.4 Agent-based model of the labor market with firm and worker-consumer agents

In the second, less experimental agent-based model, a labor market is modeled by having both firm agents and worker-consumer agents. Here, we provide just a general outline of the model, skipping details. In this ABM, firm agents are active in one of several sectors and produce products in demand by worker-consumer agents. Firm agents fire workers when product demand is lower than production capacity and attract & hire workers by increasing wages when product demand is higher than production capacity. Worker-consumers spend their wages on consumption of products produced by the firms in the economy and seek to improve their wage by applying to vacancies of firms. This effectively creates the foundation a wage-price spiral, whereby higher wages increase product demand, which in turn increases demand for labor and thereby wages.

When it comes to the effect of robotization, firm agents are actively engaged in robotization of production. This robotization increases productivity of workers and thus -at equal product demand- reduces demand for labor and reduces the price of products produced. So, without the creation of new jobs, robotization would decrease employment, thereby product demand, and thus further employment. However, when new sectors emerge, new jobs are created and there is competition for labor, whereby wages increase, product demand increases, which makes competition for labor even fiercer.

Moreover, for the production of a single unit of product, both low-, medium-, and high-skilled labor is required, which is provided by the worker-consumer agents.

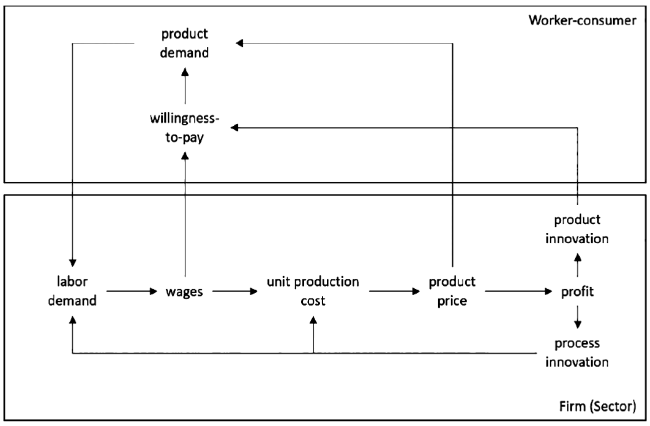

Figure 7. Schematic overview of the labor market ABM. There is interaction of firm agents hiring workers by offering wages (which determine product prices), while workers (being consumers at the same time) spend their wages on consumption of products of the firms. As the pool of workers is limited, robotization of production (process innovation) increases productivity, reduces demand for labor, softens competition on wages, and thus lowers product demand.

As described before, one of the primary attractions of ABM is the ability to conduct 'what-if' studies. In the case of our labor market model, we implemented a 'policy laboratory' to study the impact of the following three policy interventions. Firstly, the effects of a robot tax, which lowers the rate of robotization and thus the increase in productivity. Secondly, the effects of a universal basic income, which increases product demand and thereby employment (and possibly wages). Thirdly, the effects of the rate of sector creation (employment creation) and labor mobility (i.e. the efficiency of workers moving to other sectors and skill sets).

Output of an early version of this model is contained in Deliverable 8.1, an updated version is described in a working paper forthcoming in the GLO series, and further elaborated on in a handbook chapter:

– Vermeulen, B., Pyka, A., & Saviotti, P.-P. (2020). Robots, structural change and employment: future scenarios. In: K. F. Zimmermann (Ed.), *Labor, Human Resources and Population Economics.* London: Springer Nature.

Note that the underlying taxonomic framework on structural change is published in:

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