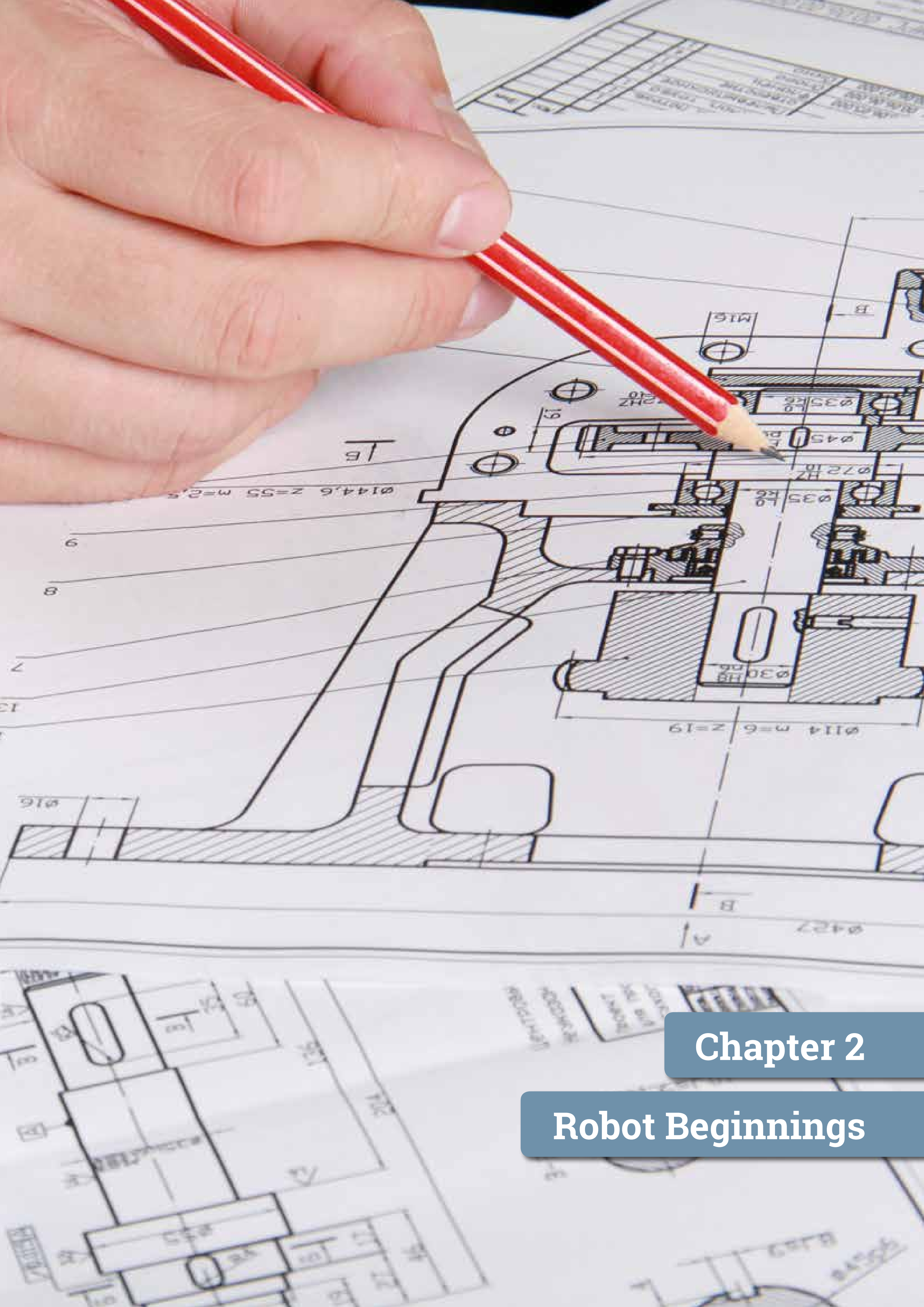

Chapter 2

Robot Beginnings

”

Well, you know. I had a mother, who was getting old, and she was living in Como, which is a town close to Milan, but not so close. And at some point, I realized that she needed some help. On the other hand, I knew that she didn't like to have someone around in the house. At that point, it would be perfect to have a system like MoveCare, so that I could connect with my mother and speak with her...This system could help her with a couple of tasks that are fundamental, when people become old. One is the request for help, so that my mother could feel safe at home. She could always call for help, and she could have a system where a robot comes there and connects her with me. The other was looking for things that she was forgetting, more and more frequently. And out of this idea, we started reasoning, and we started thinking that the robot could be paired with other elements, like smart objects, internet of things, demotics... And this system would try to keep my mother from isolation, as she was getting more and more alone as her friends were passing away, and she was not keen to go out so often, and so forth. So this basically was the motivation.

(Alberto, robot developer, REGAIN)

◀ A robot's beginning often frame the rest of development.

2. Robot Beginnings

Why end-users are absent in the early stages of design

You will find here

- An overview of REELER findings of how the initial stages of the robot design and development are tied to different types of ideas and motives
- Specific organizational and individual motives for developing robots
- A critical look at public funding in robotics
- Potential explanations for the absence of affected stakeholders in early stages of robot development

You will acquire

- Awareness of how to engage in critical reflection on ideas, motives, and practices that may influence development in its initial stages
- Awareness of what is necessary for developers to overcome barriers to affected stakeholder involvement in robot development processes

Why do people make robots? How, when, where, and why does the initial idea of developing a particular robot emerge and eventually evolve into a prototype or finished product? We have asked these questions in our 11 ethnographic case studies and in the analysis of the data collected. As noted in the introduction, all of our case-studies represent different robot types and sectors, including healthcare, agriculture, industry, entertainment, logistics, etc. Across these cases we find a lot of variation, but also some patterns in the robots' beginnings.

A key finding from REELER's research is that technology drives development. It is seldom the needs of end-users and other affected stakeholders that is the inspiration or driving force behind robot development. To understand why this is the case, REELER has analyzed the beginnings of each of the robots studied in this 3-year project.

Across REELER's cases, we find that both ideas and motives for developing robots tend to come from what is 'at hand'. When forming ideas for new robots, robot developers often begin with existing robots or previous projects, familiar collaborators and funding schemes. In fact, this is how **innovation** is often defined – taking something familiar and finding a novel way of using it (*see 6.0 Innovation Economics*). Robot developers often collaborate with facilitators (those requesting the robot or providing funding) whose ideas might be the catalyst for development. Even with a shared goal of developing a robot, the actors involved (collectively termed robot makers) may pursue its development for different reasons. The leader of a start-up robotics company might have the motive of attracting investors whereas an engineer from the same firm might have a motive of solving a particular technical problem. Like ideas, their motives emerge from the **sociomaterial worlds** they come from (*see 7.0 Learning in Practice*). Robot makers have learned to align motives with a number of actors within the inner circle of robotics (*see 3.0 Collaboration in the Inner Circle*), but often do not align with affected stakeholders whose sociomaterial worlds can be somewhat distant from their own.

> **Innovation:** *Exploitation of an invention (i.e. using something existing in a novel way). Invention is the discovery/creation of something new.*

> **Sociomaterial world:** *A mix of social, cultural, material, and temporal influences that continuously shape one's framework for experiencing the world.*

This text addresses the ideas and motives in new robot development – the driving forces behind *why* a particular robot is made – and asks whether these robot beginnings are in line with empirically identified human needs and societal concerns. First, we differentiate between ideas and motives and explain how both are informed by sociomaterial contexts. Then, we explore actual robot beginnings based on particular patterns of ideas and motives identified in REELER's cases. Finally, we explore the absence of affected stakeholders in robot beginnings and we consider factors which constrain robot makers from involving them directly.

2.1 Ideas and motives

2.1.1 Ideas

Ideas for robots may come from robot developers, from robot buyers, or from funding bodies, and they often take inspiration from existing technologies, from robot buyer requirements, and occasionally from identified human needs. Sometimes it is facilitators (public funding bodies, e.g.) who have the initial idea for a robot. Very often in industrial robotics, a robot buyer approaches a robot developer with a particular robotization request or collaborates with the robot developer as an application expert to identify an optimization opportunity (*see 9.0 Economics of Robotization, section 9.1.1*). Particularly in robotics research and development, it may be the case that a (public) funding body puts out a call for funding, to which robot developers answer. Sometimes these are open calls or they may be specific to a particular identified public need. It may also be that the idea for a robot comes directly from robot developers, without involving a facilitator. This is often the case with start-ups and with established robotics companies whose focus is on product development.

Thus, ideas for robots seem to emerge only from robot makers within the inner circle. These patterns of beginnings consistently exclude the eventual end-users and directly affected stakeholders, understood as the people who will actually work with or be affected by the robot, from being involved in the initial phases of conceiving robots. We mention this here, because these beginnings are crucial to the way the development proceeds. Robot makers' curiosity and inquiries are constrained by the limits of their gaze, their familiarity with particular materials and settings, previous experiences, and by structural constraints like the need for funding. When the idea originates in the inner circle of robotics – i.e. a particular sociomaterial culture – affected stakeholders and their motives may be excluded from the development process. A poor alignment between robot makers and affected stakeholders can result in many ethical issues (*see 4.0 Ethics Beyond Safety*). Therefore, this text will focus very closely on the patterns across REELER's data that show how ideas for new robots are typically formed, and how one's motives matter in bringing these ideas to fruition.

2.1.2 Motives

Motives are the driving forces for moving from thought to action, from an initial idea to the actual development of a robot. Motives are tied very closely to what is most prevalent in a person's purview: they may be individual like a passion for problem-solving, or may be tied more to organizational needs like getting a product to market to generate a profit. In searching REELER's data for reasons why robots were created, we find two types of motives:

1) *Stated motives*, which are tied more to the ideas behind a robot. A stated motive could be an historical account of how the robot idea formed or a defined purpose of the robot (e.g., to relieve workers of heavy labor).
2) *Object motives*, the underlying reasons for the development activity – E.g., developing a robot to get a product to market (to make money).

There can be many different motives for doing one's work, but here we focus on the *object motives* – those that direct one's activity toward a particular shared goal.

In robot development, how a robot is perceived or interpreted by a person or organization shapes their motives in the development process. Anne Edwards writes that the object of an activity gives it its direction (Edwards 2007, 7). In robot development (the *activity*), the robot end-product is the shared goal (or *object*). "The idea of object motive importantly recognizes that our actions are elicited by our interpretations of the object" (Edwards 2007, 7). Therefore, a robot developer forms his (most robot developers are male) motives based on his own understandings of the robot as an object of development activity. Whether he considers the robot a research problem to be solved or a product to be brought to market will affect the decisions he makes in the development process (Sorenson 2018). His motives emerge from what is at hand in his own world which has been molded and bound to some extent by his disciplinary background.

In analyzing REELER's data, we find it is not only robot developers who direct development activities. Because robot development often involves many different individuals and organizations (*see 12.0 Human Proximity*), there may be a plurality of motives compelling a single robot into being. Robot buyers, for example, are often involved in development and may take on different roles even while their motives remain the same (*see Figure 2.1*):

- As **end-users**, who will buy and use the robot themselves, they create market demand or define requirements for a customized solution.
- As **application experts**, who are part of a project team, they give input on application-specific manual processes, workflows, or the robot's surroundings.
- As **spokespersons**, brought in as 'end-users', they give feedback on the design on behalf of actual end-users.

The robot buyers' object motives – the reasons for performing the aforementioned roles and taking part in the associated activities – may differ from the robot developers' reasons

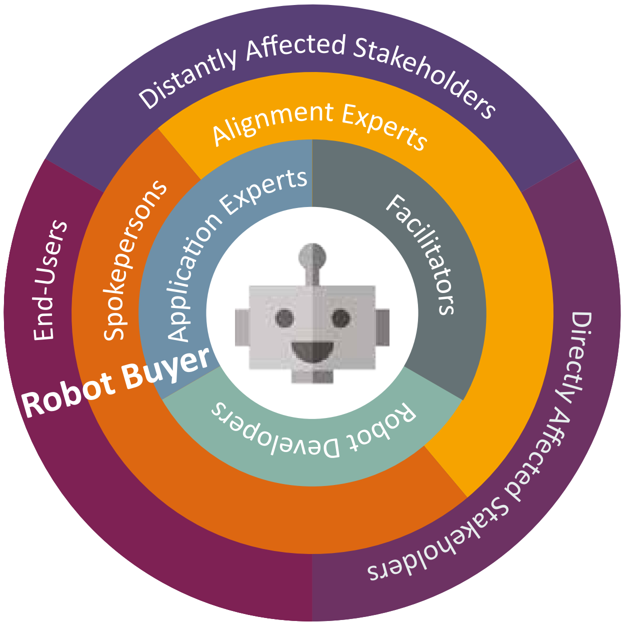

Figure 2.1. Robot buyers can take on different roles in development.

for their role in creating a robot. In working toward a shared object, these robot makers must learn to align their collective motives (*see 12.0 Human Proximity*). Generally speaking, a person's motives are formed from the *sociomaterial world* that person inhabits. However, a person does not exist alone. Rather, a person is embedded together with other persons and materials in a shared social and cultural space created from their interactions. In these interaction spaces, worlds collide and are permeated by new information/experiences, transforming the individual worlds and complicating separate understandings of the object. Therefore, one's own world is not fixed, but is constantly adapted through experience –which also means that their motives, which are shaped by their world, can transform.

Further, our cross-case analysis identifies a difference in shared *organizational* motives and *individual* robot developer motives. Although there is some overlap between organizational and individual motives (after all, organizations are composed of individuals), for analytical purposes we will first discuss individuals followed by organizations, as we present particular patterns of ideas and motives identified in REELER's cases.

2.2 Individual motives

REELER interviewed robot developers about how they first became involved in robotics, how their specific projects got started, and what the purpose or goal of the robot is. What we observe is that robot developers' work begins very close to home, driven by their own *passion for robotics* and a dedication or confidence in their *previous work*. These are the object motives we observe in nearly every project. However, we have also gathered *stated* motives – i.e. the reasons robot developers give for making robots. *Doing good* is a primary stated motivation – which is something we acknowledge but also dissect in section 2.2.3 (*see also 10.0 Meaningful Work, section 10.3*). Of course, whenever a person is engaged in paid labor, making money is a consideration and a motivation – but we rarely see money as the motive that really drives an individual robot developer to continue his everyday work.

2.2.1 Previous work

The most consistent pattern across is one beginning with an available technology, and people who have already formed at network around this technology along with funding opportunities. Sometimes the idea of the particular robot forms the basis of the founding of a new company, at other times the new robot is developed within an established company in search of new applications for an existing robot, or an established company with many technology projects, who venture into a new field of robotics.

In some cases, new ideas and projects in robotics are the continuation of previous projects that were carried out by a given group of robot makers. Previous work also refers to networks that robot makers are part of. Continuation may refer to addressing a similar subject as well as involving a similar consortium or a group of collaborators (*see Story from the Field on design and development processes in section 2.4.3*). On the one hand, such an approach helps building on the previous knowledge and experience as well as further develop one's expertise in the robotics field and a related community. This is particularly important in a situation where the design process and collaborations are distributed between different persons, locations and phases; where it may be difficult for a single person to have a complete knowledge of the project history and related developments (*see Story from the Field on distributed ethics in section 4.3.1*).

2.2.2 Passion for robotics

It is clear that passion for robotics runs across all cases in our study. The robot developers are passionate about building robots and have a lot of fun doing it. A number of the interviewed robot developers point to their personal interest in constructing robots as the main motive for developing robots.

Interviewer: And how would you define a robot?

Daniel: I would say tool … versatile, especially for humans. Passion obviously for me, I am very passionate about robotics.

(Daniel, software developer, robot developer, BUDDY)

Here I am really in my element, that is my passion, and I am really blooming here. And because of that, I believe, I can perform well in my job.

(Stefan, mechatronics engineer, robot developer, COBOT)

In many of our cases, we see that robot developers really love their work and would not give it up, even for a universal basic income (*see 10.0 Meaningful Work*). Robot development has a level of playfulness to it that can best be described as puzzling. Engineering is largely problem-solving work and in robotics this work takes a very physical form where a developer's decisions on a computer screen correspond to real action in the world. Observing robot developers at work is not unlike observing children at play. They can become completely absorbed in solving a particular technical challenge through creativity and innovation. In fact, some of this playfulness is cultivated in robot competitions, which some robot developers engage in especially at the early stages of their careers. In addition to being fun, robot competitions also often serve as an important starting point to attract the interest of mass media and potential partners or investors, as well as to give confidence to robot developers to pursue their projects further.

Robot developers often start with their own interests and experiences, which can be very good for society if the interests are aligned with societal needs (like Alberto building a robot to support his elderly mother's independence). In research-oriented development, we see robot developers have more freedom to follow their interests, whereas they are more constrained by the product- and customer-oriented developments.

It is not so easy to find such a job where you can be pretty free as a developer. So, sometimes you have pretty narrow requirements and you only hear: "Optimize this in this and that direction". And here you can come up with a new concept, build that up and figure out does it work, does it not work. And yes, that is exciting.

(Valerie, mechanical engineer, robot developer, COBOT)

For those who enter product development, we see that they try to find a way to blend their passion and individual interests with the monetary interests demanded at the organizational level, though sometimes they must compromise their own ideas to meet market demands.

I mean we fairly early on said: "Yeah, we want to do that and we want to build [an autonomous car] as a service and we want to do it in the urban environment because that's cool and interesting and fun and it's where actually you can have the most impact generally." And then, for various reasons in terms of funding, we had a period where we said our go-to-market was going to be more a licensing business, but we always kind of felt our heart was in the service business really.

(Sebastian, CEO, robot maker, HERBIE)

Across cases we see that this problem-solving activity is not only applied to technical challenges, but that robot developers are also interested in solving human or societal problems with technological solutions (Sorenson 2018). This ties into another motive, *doing good*, as seen in the autonomous car example above.

2.2.3 Doing good

Many robot developers report doing good or having a social impact as a motivating factor for developing new robots. However, when we look across the different stages of robotics, we see that the *ideas* for building robots are seldom motivated by meeting others' needs. Here, we rely on the distinction between *stated* motives and *object* motives. Doing good is often a stated motive – that is, it is a factor in their thinking about the development, but it does not drive the development. If it were not possible to 'do good', the development would continue (*see 10.0 Meaningful Work*). Put another way, it often turns out that a robot is incapable of fulfilling the good it was intended or promised to do.

This was the case of the robotic start-up in the logistics industry whose founders decided to deliver robots that are 'affordable to all'. At the same time, the company would carefully target its customers and engage with B2B marketing.

> *So, the idea of the company is actually to create robotics that are accessible. It's not as expensive as people — I mean, it's still not going to be cheap yet, but it is acceptable and it's affordable and more companies can employ robots. (…) It's not just working for giant companies who really can spend millions on automation. Our idea is affordable robotics for people.*
>
> (Alph, start-up CEO, robot maker, WAREHOUSE)

Although they could not make the robots affordable for all, they did continue to follow their mission to develop robotic systems that benefit people. However, this company was largely founded on external Russian capital, which puts organizational needs for profitable investment and individual motives of affordable robots somewhat at odds. This case is a good example of product-oriented design thinking being focused on robots as 'solutions'; both in the sense of performing tasks but also as solutions to specific problems people might have within their organizational cultures and environments.

> *Design again, the idea is we do robotic solutions. We do the solutions to help people to work. And then, okay, what's going to be our first application of this attractive solution.*
>
> (Alph, start-up CEO, robot maker, WAREHOUSE)

Whether the market-oriented approach actually brings robots to the market for the benefit of end-users and not prevalently for commercial benefits, depends on the priorities assigned by robot makers and our socio-economic system as a whole. Even with the many good intentions to create robots for people, the robot makers still lack a closer contact with the actual people they envision to help out in their everyday lives. Even if robot solutions may be profitable for a company this is not the same as helping people on the shop floor (*see section 2.3.2; see also 9.0 Economics of Robotization*). Sometimes, individual robot developers aims are complicated by structural factors and other patterns of activity.

When individual robot developers' activities are driven by or constrained by the strategies of the company, institute, or university they work for, we call these forces organizational motives. Just as individuals comprise an organization, individual motives underlie the ideas and motives of organizations, which are presented in the section that follows. Therein, we see that previous work, passion for robotics, and doing good are all integrated into the work done on an organizational level, but are subservient to the overarching organizational motive of making money.

2.3 Organizational motives

Across REELER's cases, we find that robot developers have different motives for designing robots, which are not all tied to bringing a new type of robot to the market. However, given the nature of the industry, all of the robotics start-ups and companies studied within the REELER research followed commercial objectives to a varying degree. Other organizations may start their activity or specific robotics project with a clear profit motive in mind. While still others are approached by a customer with a particular need for a robot. Finally, there are those who focus on research experiments or the research side of full product development. Such an approach involves not only the decisions of robot makers but also the motives of those providing funding and/or interest on the investors' side. In such a case, business interests are closely related to design interests and the two evolve together.

> **Business case:** *An argument for robot development based on expected commercial value*.

> *Many times, we develop the business cases, we develop the robot, because then we also make adaptations to the robot design and the specifications regarding that. I think, when we started, we had a basic business case, as we had a basic concept of robot and I think both evolved side by side.*
>
> (Oswaldo, industrial designer, robot maker, SPECTRUS)

In REELER, we categorize the robot beginnings in our cases as:

- *Product-oriented*, where the robot emerges from ideas for new product development or expanding to other applications or markets, from which the organization expects to make a profit.
- *Customer-oriented,* where a customer initiates development and comes with requirements for a robot, from which

the robot development organization expects to generate revenue.

- *Research-oriented*, where the robot is initiated from calls for funding and the aim is to explore new applications or functionalities in robotics.

In product-oriented development, it is often the robot developers that come with a new idea for a robot, whereas in research-oriented development, new robots emerge because robot developers tailor their robot idea to a specific call for funding, similar to when robot developers are approached by an 'intermediary' like a robot buyer with specific demands. In all cases, whether intended for mass production or answering a particular demand, all organizations have to keep an eye on the bottom line. Unlike individual robot developers, organizations' motives largely concern earning money, though they may go about it in very different ways (i.e., profiting from sales, securing research funding, or generating revenue from services provided to robot buyers).

Sometimes, a single robot project can involve multiple organizations spanning these three robot beginning types (e.g., a research-oriented institute or university developing a prototype robot, a private company commercializing the robot, and a customer giving input on requirements and perhaps implementing the robot). Even when a robot is developed outside of these coalitions, perhaps in a robot company alone, public money is nevertheless often traced to development activities. That is to say that public money is heavily invested in robot developments of all types, in all sorts of settings, and dispersed to all sorts of organizations.

2.3.1 Product-oriented

The motivation to generate profits through new product development entails a desire to put a product into production and sell it to a wider market. This is an approach to robot development that is initiated by robot developers with the motive of turning a profit. The product-oriented approach is especially common among established robot manufacturers, but was also common to start-ups. The start-ups tend to have a passion for robotics and a desire to churn passion into profit. Large companies have different types of resources that allow them to turn their ideas into actual products (often branded under the umbrella of 'innovation'). In fact, large robot manufacturers often invest in R&D on a continuous basis through their own R&D divisions, and sometimes in collaboration with public funding bodies or in affiliated research institutes. From this perspective, a single organization may be project-oriented but may nevertheless engage in research, inasmuch as it contributes to new product development or strategic competitiveness.

The product-oriented approach is developer-driven and organizations that are focused on product development have a tendency to begin from what they know. New product development is often cultivated from existing technologies and product lines, involving familiar players. Similarly, a lot of start-ups and robot companies emerge from university researchers' existing collaborations.

STORY FROM THE FIELD:

Commercializing innovation

One example comes from a group of young robot developers who have successfully developed an educational social robot. This group included persons who knew each other from a robotics department and related activities at a university. While affiliated with the university, the group became involved in robotics competitions. The first shared goal the group set for themselves was to deliver a proof-of-concept and demonstrate feasibility of their solution. The group successfully displayed a robot resembling a sumo wrestler at a national competition. While the judges and the audience (including would-be investors) appreciated the technical side of the solution, they also criticized the aggressive aesthetics of the robot.

We created the first version of the robot which very much reminded a sumo wrestler and we managed to win one of the local competitions with this robot. Everyone was delighted with the solution. But then people approached us in the lobby, they patted me on the shoulder and said: "Well, a great solution, but do something with its look – it doesn't look nice." (Matis, co-founder & marketing, robot developer, ATOM)

In order to exploit the initial success of the robot and to engage further in robotics, the robot makers decided to set up their own start-up.

We won the national finals. And immediately, when we sat down to the project, we decided we wanted to make a product that we were going to develop that was able to achieve some business potential. Participation in the competition allowed us to acquire the first investor, which allowed us to bring the entire product to production readiness, and at the same time to get the partners we wanted. (Matis, co-founder & marketing, robot developer, ATOM)

We invested all our savings [laughs] at the development phases. At the beginning, we wanted to have a try to see how it goes. As it turned out, let's say the idea itself caught on … enough to decide to invest in it both time and money. At some point we decided to make a business out of it. (Leon, co-founder & CEO, robot developer, ATOM)

Gradually the company manage to attract significant private investments (with only limited participation of public funds) and the start-up began scoping out the market for a potential application. The robot had begun not as a product, but as a provable concept, but along the way the robot developers got feedback from different people that influenced the final design. They were not able to identify the exact moment that their idea became centered on educational robots, but by working together on the prototypes, the idea for ATOM gradually became clearer.

If we go back in time to the very earliest days. At the very beginning, the idea was to try to combine IT education or IT experience with the robotics experience that people in our team had. And initially, we wanted to try to bring a computer game to the real world, so that instead of playing on a computer screen, it could be done on the larger room floor. After a few modifications we came to the conclusion that we should try to teach children something and we came up with the idea of an educational robot with a strong focus on entertainment. Our first concept was to create the robots that were going to fight with each other. (Leon, co-founder & CEO, robot developer, ATOM)

The start-up's market-oriented motives led them to making repeated modifications to please their target buyer group.

The children would program robots so they can fight. For children it's a game. But for parents, not really. And there we were getting information whether we should soften it, trying to keep this entertainment aspect and smuggling some education underneath. But that it would not be something that can be associated with negative emotions. Therefore, in subsequent iterations of the project – the next modification was to create a robot that was going to teach children the basics of programming and develop the ability of logical thinking, but of course ensuring competition, too. So elements that allow children or encourage children to work longer with the solution, not only to play with it 15 minutes and put it in the closet, because all functions were already recognized. And it was one of the key stages related to the fact that we brought our idea to a certain point where we knew, and all agreed, that it was it and where the market response was also: "Ok, we want it." (Matis, co-founder & marketing, robot developer, ATOM)

In this product-oriented approach, the focus in the robot design was building a technology which could sell. The focus was not the application, nor the end-users' (the children's) needs. Part of the success of the company and its product was in the relative early phases extensive engagement with end-users and collaboration with other experts that helped creating the robot. This is how, while initially starting from their own individual interests, robot makers shifted their perspective towards user- and market-oriented design thinking to further design and develop a social educational robot.

(Based on interviews with Leon, co-founder & CEO, robot developer and Matis, co-founder & marketing, robot developer, ATOM)

A similar approach was followed by a small group who set up a robotic start-up in the area of logistics. The goal was to see if the solution they had in mind was feasible rather than to meet specific end-user needs. As in the case of the educational social robot, this group of developers initially invested their own funds and developed the first prototypes in their own apartment and garage – with an eye to eventually create a marketable product and a viable business.

> *So, the guys realised we can make it work. That was the first conclusion. The second was, if we can make it work, then we have to actually make it more than just a hobby. Then it becomes part of the foundation of a start-up or foundation of the business.*
>
> (Felix, CEO Advisor, robot maker, WAREHOUSE)

As pointed out by one of the robot developers in the educational social robot start-up, in order to be successful, the idea for a product must be supported by thorough market research (which includes the assessment of the customer requirements) and not simply be based on the convictions one might have.

> *First as we develop research, we investigate the market and try to develop a product according to customer requirements. And as a result of this process, we have a so-called ideation; the creation of an idea. Then we ask ourselves and the customer a lot of questions, we do a brainstorm that leads us to the final form (…) And always the design is a solution to some problem, it is an answer to a question (…). There are always some design assumptions. (…) The design process does not begin with the fact that a designer has a robot in mind and sketches it, it is always backed up by some research. Research and customer requirements, in particular the functional requirements for that object.*
>
> (Igor, design studio, robot maker, ATOM)

While such approaches initially are far from the user- and society-oriented design thinking, market-oriented start-ups and companies inevitably have a strong desire to see their robots being accepted in the public. Therefore, closer collaboration with the actual end-users (not just potential buyers of commercial robots) in the early stages of design could be a benefit to the budding robot developers. As illustrated in the above quote, however, we see across cases that robot developers tend to conflate customers/clients with end-users.

Thus, product-oriented organizations tend to spin new ideas from within the organization, relying on the same network of players and beginning with existing technologies or past experiences (*see section 2.4.1*). Sometimes, these approaches involve market-research with potential customers to define the robot's design and/or application. However, these insulated beginnings often omit the end-users and their motives from being taken into the design process (*see section 2.4.3*).

2.3.2 Customer-oriented

Just as product-oriented development is focused on making profits, the development of robots for customers is driven by a desire to generate revenue. The customer-oriented approach (sometimes called 'commercial development') differs, however, in that each robot system provided is a one-off solution that is tailored to a single robot buyer's needs. The customer-oriented approach is most common among research institutes and system integrators in industrial automation. This approach was also surprisingly found among Silicon-Valley style start-ups, whose goal is to develop a working robot prototype and validate the market for the product with the purpose of being acquired (or selling off the fledgling product idea). In all cases of customer-oriented development (among research institutes, system integrators and these particular start-up types), the initial need for the robot originated from the robot buyer. This means the robot developer must contend with the buyer's motives, which are usually tied to competition – whether this means remaining cost competitive through production rationalization, or remaining strategically competitive by meeting social expectations of digitalization *(see 9.0 Economics of Robotization for a detailed discussion).*

In this chapter, however, we focus primarily on the motives of the robot developers, and in this section, why they engage with robot buyers to create customized robots, and how they are able to make a business out of this approach.

In METRO, one of the robots in the OTTO case, a robot developer was approached by one of the leading providers of metro services in a particular European country. The two organizations had an established relationship, having already collaborated on other occasions. Together, the robot developer and robot buyer identified a problem that could be solved by automation. As pointed out by one of the robot developers, customers typically come with a problem to be solved and not with a concrete idea for a solution.

> *Interviewer: Did they come to you to ask to develop this robot?*
>
> *Bart: No they asked us to develop a solution, because a customer doesn't know the solution; he only has a problem.*
>
> (Bart, business developer, robot maker, OTTO)

This is typical in industrial automation (e.g., in manufacturing and production), but also in inspection and maintenance, agriculture, and other sectors where specialized machines have traditionally been used to automate tasks. With an increase in service robot applications, we also see customer-oriented development in healthcare and hospital settings.

Often, a potential customer approaches the robot developers, or the developers send consultants to the company to examine a work process and identify a task particularly suitable for automation. With the problem defined, the company comes with requirements for the solution, from which the developers draw up specifications. So, while the development may be initiated by either the developer or buyer, the choices in development are heavily influenced by the buyer and the buyer's motives.

It is important to note that the robot developers in the OTTO case did not have any knowledge of metro systems prior to their collaboration with the robot buyer. This is often the case in customer-oriented development, in which the robotic company learns about the given field of application only through the development process – not before. Thanks to an open and collaborative approach demonstrated by both parties and extended periods of time spent together in the field with the actual metro workers, the robotic company managed to design and adjust robots in a way that met the requirements of the metro service provider as well as the workers involved.

> *We started with a structure of tubes, with the prototype Zero [laughs], or rather below zero, and from there we began the adventure that really in the last few years has led us to do hundreds of tests. (...) Of course by bringing some of my knowledge to them because they arrived completely ignorant on the subject, they basically did not even know what they should be looking at. Because the sector was completely new to them. So, they made a significant leap of knowledge.*
>
> (Bart, business developer, robot maker, OTTO)

Involving people with contextual knowledge of the application area is crucial for starting the design process with a shared understanding of a problem and in aligning expectations that might later translate into actual robot features and functionalities. An advantage of such close collaboration between robot makers and robot buyers is the opportunity to gain first-hand, on-site knowledge of the process to be automated. However, just as in product-oriented development, customer-oriented development may be insular, involving only those people who have already entered the robotic bubble – the inner circle of robotics. We have seen across cases that these customized commercial projects often start with participation of *intermediaries* like the company manager who is in the position to articulate the company's demands, or a production engineer who might have insight into requirements or specifications for the robot – but this does not mean that actual end-users or robot operators are included. (With METRO, however, this was not the case. End-users were consulted often and early on.) We argue that approaches where a robot meets the customer's demands is not necessarily the same as applying an end-user-oriented approach. And, for many product-oriented robot developers, it is *only* the robot buyer's needs or requirements that matter in design – the actual users' needs simply are not a consideration. In fact, the buyer's needs and the end-users' needs may be at odds if, for example, the buyer is acquiring the robot to automate part of the end-users' tasks (*see 10.0 Meaningful Work*). What is important in robotics, and what is as yet unaddressed, is the need to align the motives of the robot buyers and the robot developers with the needs of the users. Persons expected to use the robot ought to get some say in setting the requirements.

Publicly funded projects are often expected to promise some kind of market potential, even if the motivation is research.

2.3.3 Research-oriented

A third group of organizations develop robots primarily on the basis of research funding, which occasionally becomes a satisfactory way of earning a steady income. The stated motive of research-oriented development is to advance the field of robotics, while the object-motive of organizations engaged in research is the funding that drives many of the research institutes and technological development companies that rely heavily on research funds to cover the costs of their daily operations.

We also see research in large successful companies, even if research is not their primary motive. For example, one large company which was not specifically involved in the REELER project, but illustrates very well an archetype in our research, is a robot manufacturer with an established industrial robot product line, but which invests in R&D. Most of the robots coming out of these processes are not meant to go to market, but are used in marketing and contribute to the company's brand image. Although the company describes their core product line as industrial automation solutions and their products page features components such as actuators, motors, controllers, and sensors, their social media channels feature exotic robots from their experimental R&D division, with zoomorphic and anthropomorphic features. These robots are disproportionately represented in media campaigns, especially considering that less than ten percent of the company's turnover is invested in such R&D. Although not intended as products themselves, marvelous machines boost the company's product-oriented business. The imagery the company produces demonstrates an interest in maintaining an image as an innovative organization (*see 9.0 Economics of Robotization and 8.0 Imaginaries*).[1]

This type of R&D activity is different from research-oriented organizations whose primary goal is research. In product-oriented organizations, R&D still feeds into new product development – where breakthroughs in lightweight sensors in the company's biology-inspired robots might be taken up in industrial automation, e.g. Nevertheless, we see an entanglement of product-oriented organizations with publicly funded research.

Although research is a phase in product development, the major differences between product- and research-oriented development are the source of the idea and the object of the development. Research projects usually are framed by some sort of call or funding guidelines which may already delimit the application areas, sectors, or problem area that the robot should solve. Some research projects are not unlike the customer-oriented robots, formed around a buyer-defined need, except that these projects are publicly funded and the resulting robots are typically prototypes or experimental solutions – not products that will be scaled.

In this context, one of the REELER cases involves a cleaning robot developed for the hotel industry. The robot was created by a start-up and a spin-off company that later became a part of a local cluster bringing together academia and industry. The cluster has been created with the support of both a local university and local government funds. In this sense, the company was part of the deliberate efforts and investments made on the side of the government to strengthen the robotics industry and its collaborations in a region. The robot began from an open call from hotels and regional tourism authorities for cleaning technological solutions. The design and development started from developing a concept and a business plan, to later creating a prototype, and the company does hope to eventually have a market-ready product (scalability and commercialization were part of the grant proposal).

Although the robot was built upon an existing mobile platform, the entire process took several years before the robot was ready for implementation (and it is still being fine-tuned although it has been implemented in a few hotels). In this case, the entire project was strongly bounded by national frameworks, both in terms of funding sources, participating tests sites, and the outcomes of the project. As it turns out, the robot did not prove transferrable to other hotels outside of the European region where it was designed (see inclusion/exclusion). Nevertheless, the start-up continued to make new robots, many of them funded in part by public research funds, with similar results.

Research-oriented robot development blends organizational interests with public and private interests. Thus, there are multiple motives at play. At any given time, the start-up that made the hotel robot had five or six publicly-funded research projects running. This is a pattern we have noticed in research-oriented organizations. Research funding becomes a dependable revenue stream for some players. Depending on the source and type of funding, such an approach may foster specific forms of collaborations and problem-spaces that may be limited to only specific networks, cultures, and design practices. Once again, there is a risk of development occurring within a specific 'bubble' where robotics projects are initiated with very little consideration for the perspective of the actual end-users and affected stakeholders.

2.3.4 Blurring the lines

Whether organizations intend their new robots as products, as services to customers, or as research experiments, the robot developer organizations are all driven by making money. While there is nothing wrong with an organization having monetary interests, REELER finds that public money is often involved in robot development no matter the organization's standing as a private company, research institute, non-profit. Public money is heavily invested in robot developments of all types, in all sorts of settings, and dispersed to all sorts of organizations under various commitments and conditions. This means that public funding is also implicated in the many ethical issues REELER identifies in the other chapters.

We see private robotics firms taking part in publicly funded research projects, or getting their own start from early government investment in robotics. We see research institutes and other technological development organizations living from project to project, paid by public funding. We also see automation experts partnering with robot buyers to seek public funding to offset labor costs for developing customized

1 For a brief explanation of R&D for publicity, see: Metz, Cade. 15 October 2019. If a Robotic Hand Solves a Rubik's Cube, Does It Prove Something? *The New York Times*. https://nyti.ms/31hLzLp

solutions. All of our cases fit these three archetypes to some extent, though money is rarely stated as motive.

REELER interviewees rarely mention funding as a reason for taking up robotics. Still, we find that ideas and motives are tightly coupled to earning money, and we find that the boundary between the public and private sector, and related funding, is often far from clear. Nevertheless, the financial basis of 2 of 11 REELER cases is solely public funding and for the remaining 9 cases - irrespective of whether the work is conducted by private companies, research institutes, or universities – public funds have supported the robot projects. And some projects can be extended repeatedly for years without the robots ever coming to market.

It is important to note that public funding schemes often encourage commercialization of robotic technologies as a way to bring robots to the society – but as shown by the REELER data, public funding is not naturally or overtly connected to product-oriented development. When the same groups of robot developers are funded over and again, robot innovations that were meant to be disseminated and to contribute to economic growth, never actually leave the lab. The technologies of one project become the basis for the next. In this sense, public funding schemes are gradually becoming a sort of business.

I think we can have some nice opportunities, because the European government provides a lot of money in case of European projects. The only problem is that these kind of projects, ten years ago were really easy to access. Now it has become a business, so now there are persons – lawyers really – that just do this job; to support a big company to achieve the money, to take the money from the European project. And so, the small company does not really have the opportunity to have the kind of economical support.

(Alessio, Start-up CEO, robot developer, COOP)

In overtly public research projects, robot makers often respond to specific funding calls that determine a problem which requires a robotic solution. In this sense, the responsibility for design ideas and the consequences of design also falls on public funding bodies, including policymakers. Whether these funding bodies have a good understanding of citizens and societal needs is an open and necessary question. If public funding has such a heavy hand in determining the forms that robots eventually take, great care ought to be taken to ensure that these investments serve the public good.

Investment of public funds in robotics has been going on for a long time. Take the case of one major industrial robot manufacturer studied in REELER. The history of development of their robots started at a big public research institute that has been exploring different areas of transport and automation since the 1980s. The institute's work was initially focused on the development of lightweight robotic systems for different areas of the transport industry. Starting from the 2000s and with the support of publicly funded projects, first steps were taken to transfer the lightweight robot technology from transport applications to potential industrial applications. The transfer took place between the research institute in question and a private company with the goal of commercializing its product. The two are closely connected as some of the company employees used to work for the institute and they are located in close geographical proximity. The company in question has a long record in the field of metal fabrication. Over decades, it has become one of the world's leading companies in automation of industrial manufacturing processes. One of the main reasons for the company to participate in the transfer was to meet the demand of its main customer who was pushing towards development of lightweight manufacturing robots. It is important to note that given the novel nature of robotics technology at the time, the company heavily relied on public funding.

Public funds are often framed as investments in emerging technologies or innovation. Often, the justification for such investments is a promise of shared value from commercialization and consequential economic growth. Many public-private development projects promise accessibility, scalability, generalizability – basically that robots should be more widely available. However, in practice, REELER research shows that in many research projects, these goals are often a mirage. Thus, it may even be unethical to make these kind of promises when searching for public or private funding – especially where this behavior obscures unmet user and societal needs. The involvement of public money in robot development has not been uncommon and is confirmed in REELER's cases. But now, we contend that stakeholders are due their return on investment.

2.4 Absence of affected stakeholders

In this section, we unfold the apparent absence of affected stakeholders in robot beginnings, starting with an explanation of the familiar beginnings which so often influence the ideas for new robot development. Then, we look at the distributed nature of development and how it can be difficult to involve end-users when development is geographically and conceptually dispersed. Finally, we take a critical look at Technological Readiness Levels (TRLs) to distinguish between 'invention' and 'innovation', in order to explain how the end-user is not – or perhaps cannot – be involved in the earliest stages of technological development.

2.4.1 Familiar beginnings

All of the robots studied in the REELER project began from familiar beginnings – whether from previous collaborations, from existing technologies, or from problems already identified in past projects. When starting from what they already know, developers run the risk of isolating themselves from unfamiliar problems and unfamiliar affected stakeholders. While this approach results in a more well-defined beginning, the choices already assumed in early design stages close off other design choices and problem areas that might have led to very different development processes.

Robot developers often try very hard to engage end-users in their design processes, but familiar beginnings can render their efforts inert. In general, across different industries, robot developers face the challenge of achieving a balance between exploiting a technology and bringing end-user expectations to the table.

Many robots start with familiar beginnings, like previous collaborations, existing technologies, or previously identified problems. (Photo: Kate Davis)

When you are working at the age of research, the matter is more complicated. Because on one side, you still need to know the wishes and the expectations of your customer, it may be a clinician, or it may be the NGOs. But at the same time, technology may be more advanced in development than the expectation. So, it's a continuous tuning of technology and expectation. And you need to have both the researcher and the user together. And if you are able to have them working together since the beginning, you are able to exploit, the maximum, the potentiality of the new technology. Otherwise, no.

(Alba, head of R&D, robot maker, REGAIN)

However, several robot makers deny that the demands should come from the affected stakeholders, as they know too little of the potential of the technology.

Sometimes the customer asks a lot of things, [that are] not really necessary. And our goal is to explain to the customer which of these customizations are really important to the solution.

(Luciano, software designer, robot developer, OTTO)

At the same time, European robotics can sometimes appear to be a 'small world'. Despite efforts to bring technological and economic innovation to all European countries and facilitate their participation in robotics initiatives, the robotics projects and related design and development processes are often distributed among only limited networks and locations. Such an approach may increase bias in design thinking, situated in specific national and local socio-cultural contexts as well as narrow the perspectives robot makers take towards the affected stakeholders and robotic solutions. For example, one of REELER cases has shown that both robotic companies and university laboratories tend to prefer to collaborate within a relatively stable, homogeneous network of partners, in particular those located in the country where the company is based. As part of this case, one of the customers located outside Europe decided to pursue robots produced by a given company because, unlike some other producers, the company in question made its robots available on the customer's continent. This illustrates how not only the world of robotics may be small, but also the world of its customers.

From this perspective, one explanation for a lack of close contact and cooperation with end-users and affected stakeholders might be the insulating process of starting within specific circles of the robotics field and industry. However, it is not so easy for robot developers to simply enter into a community of practice and together identify problems to be solved by technological means, as shown in the sections that follow.

2.4.2 Distributed beginnings

Despite the intentional variation across REELER's eleven cases, we find a pattern in the way robot makers develop their ideas and the groups they form. As noted in the introduction, when we chose the sites of ethnographic work, we selected for variation in not just robot types, but also organization size, application sector, and countries. Initially we worked under a misguided – or normative - perception of how robots develop from idea to product: We envisioned that a robot, whose origin appeared to be tied to a European organization, would be developed in one place within the borders of Europe. Instead, we found that most robots develop in very international collaborations. In fact, of the 11 cases, one robot company actually turned out to be headed and founded by Russians, another has roots in China and another was at least initiated by South American developers. In all of the other robot cases, at least parts of the robot are delivered by countries outside of Europe like Japan, USA, and South Korea. Though the finding may seem banal, across cases we find that no robots are developed from scratch in a single place. A robot is a distributed technology, built from many different components manufactured all over the world, and sometimes involving modifications or additions to an already developed robot (like industrial cells built around off-the-shelf arms, or mobile robots built upon existing mobile robot bases). In all of these cases, at least some of the parts are off-the-shelf parts, which may be modified or simply incorporated into a new robot.

Further, the persons responsible for integrating different components may be distributed. A university might be developing vision systems, while a group of mechanical engineers build the frame, e.g. The fact that the design and development processes are often distributed among different persons, phases, and locations is not only crucial for the underlying design thinking and practices (and hence the successful completion of the projects), but also the approach taken towards ethics and responsibility in robotics.

As discussed in *section 2.3.3*, a company has built a cleaning robot for the hotel industry, as part of a public-private partnership to solve hotel staffing issues. As explained by the robot makers involved in the project, the process of design and development of the robot was distributed among different people participating at different stages. This was dictated by different funding rounds as well as the fact that the entire process took several years. One of the robot makers, who joined the project at a later stage, knew little about the origin and history of the project, but knew much about the development from the initial prototype to the market-ready product that he would continue to adapt. On the other hand, another robot maker was involved only in the beginning of the process in securing funding, and had very little to do with the technical development that followed. Therefore, just as it is the team that contributes to the robot design and development to a varying degree, it is necessary that different people, at different stages, are prepared to also consider ethical implications of their work. In other words, the entire team or group of collaborations shares responsibility for whatever unethical outcomes the robot's development might induce.

> *When you work in very small details in the development of a robot, you also know that you need a good, and a strong, and maybe also a decent-sized, team to create a robot that could actually have a harmful purpose. So, I don't imagine what happens in action movies that you have this one brilliant guy that creates something that could be really harmful. In my opinion, you need to have some kind of a team.*
>
> (Mathias, system integrator, robot developer, SPECTRUS)

Therefore, the initial selection of collaborators may make a difference in the possibility and timing of involving end-users (*see 5.0 Inclusive Design*), but responsibility for development across organizations and geographic regions makes it difficult to assign responsibility for user involvement (*see 4.0 Ethics Beyond Safety, section 4.3.1*). Another complicating factor of distribution is the distribution of development across time.

2.4.3 Technical beginnings (TRLs)

As participating robot developers have noted, users cannot be involved in the early stages of technological development, because the applications (and hence the relevant users) are not yet defined. Many publicly funded projects utilize technological readiness levels (TRLs) to measure the expected progress in a project. Most of the robot developers interviewed do not actually think about TRLs in practice, but TRLs do prove useful for the purpose of analysis.

TRL 1: basic principles observed
TRL 2: technology concept formulated
TRL 3: experimental proof of concept
TRL 4: technology validated in lab
TRL 5: technology validated in relevant environment
TRL 6: technology demonstrated in relevant environment
TRL 7: system prototype demonstration in operational environment
TRL 8: system complete and qualified
TRL 9: actual system proven in operational environment

From TRLs 0 to 3, robot developers are engaged in basic research, or 'invention', where the goal is to make a technological breakthrough that might be taken up in development. Innovation occurs between TRLs 4 and 9, where the initial invention is applied in a new way. It is during these stages that the application and environment is defined, which means there is an opportunity to identify potential end-users. Unfortunately, we find in REELER that few robots actually start from early-stage TRLs – or at least the idea is not always traceable.

The CUTS project is a perfect example of how a robot idea is formed and developed from familiar beginnings, by a group who have previously worked together on a similar project, and not from early TRLs. It involves both people from a technical university, a private company and some technical partners dispersed in different countries in and outside of Europe. After more than two decades of working on this kitchen robot in the company KIT (Kitchen Technology)[2], the main CEO acknowledges that the robot will not be ready for market. Following a recurring REELER finding, this robot company, does not begin by asking end-users, i.e. the people eventually supposed to work in kitchens with the robot, about their everyday practice. One of the reasons the group has taken so long to develop the robot is that they have only gradually learned about the motives of everyday people working in the application area, even while the developers' own motives have changed over two decades.

2 Some identifying details are altered to avoid violating confidentiality and ethical principles. References in the quotes are changed, but the quotes are taken from actual REELER-interviews.

STORY FROM THE FIELD:

On a design and development process

Motivated by passion

Beginning with their passion for robotics and their previous collaborations, a group of (male) robot developers decided to make a new robot. They had previously worked on a robotic device that they, as students, thought could help in the kitchen at their university. Hence, the idea of constructing a cooking aid robot for a kitchen environment began around 20 years ago with a basic concept of a cucumber-slicing kitchen robot.

One of the guys, Jannick, eventually became a CEO of the company they formed together. The robot they are developing today is a continuation of this early prototype. Paul explains about the prior cucumber project:

Then there was actually the very first robotic project which was carried out in the Uplands, and maybe also one of the first worldwide, on an autonomous cooking aid robot that could help slice cucumbers in the kitchen. This was a project financed by the Ministry of Innovation, because they said, or they could not believe, that it would be possible at all to develop an autonomous system that is able to pick up a cucumber or a fruit and slice it, when asked to. They said: "So okay, can you demonstrate that?" […] That is now seventeen years ago.
(Paul, CEO, robot developer, SANDY)

Motivated by research

The robotic team, working from a research-oriented approach, got public funding from the local government and managed to build an operational prototype kitchen robot for slicing cucumbers (though not finding and picking up cucumbers by itself). They were certain the robot could be used in private homes as well as in restaurants. However, at the time the market was not ready for this kind of robot, according to a roboticist colleague in KIT:

At that time, the restaurant owners were not asking to replace their labor yet, with robots. Maybe, this was the period at which we got a lot of Eastern European people coming from Eastern Europe to help in the restaurants. […] Restaurant owners move by economics. When they have problems with surviving and getting enough money earned, they see that labor is a problem now, so they start asking for this kind of thing.
(Michael, CUTS coordinator, robot maker, SANDY)

More than a decade after the first robot project, KIT became the research coordinator of a new robotic development project called CUTS (Clever Utensils). CUTS was a publicly funded international project answering a call for new production technologies including service robots. The CUTS project did not only focus on one specific task in the kitchen, but developed several technological demonstrators for high value tasks like slicing vegetables and fruits, and destemming grapes. However, one aim was to build a robotic kitchen prototype for handling mushrooms. A roboticist from KIT, who now work on COOK and who also previously worked in CUTS, explains the aim of CUTS project:

Paul: CUTS' idea was to build a modular robot system that can be reused for different applications. The applications in CUTS have been the slicing and peeling of different fruits and vegetables like apples, tomatoes, grapes, and precision cutting in a kitchen.

Interviewer: Okay, so it was meant to do different things?

Paul: The idea was to have, let's say, have the same robotic arm, and moreover the same software which is behind, because a lot of components are very similar. And then maybe have different kind of grippers for the different kind of tasks. That was the basic idea of CUTS. And what we finally did in KIT, was to focus on the handling of the mushrooms. That was our responsibility […]. In CUTS our partner for instance in Inland did the grippers for apples and grapes and our third partner in Outland did precision cutting equipment […]. So, there were more partners involved.
(Paul, CEO, robot developer, SANDY)

The CUTS project was accomplished four years later, at which stage the developers (an international group of more than 10 participants across 8 countries, mainly from Europe) had managed to build the first demonstrator of an autonomous kitchen robot. They had promised to reach TRL 9, to be able to make a kitchen aid robot demonstrated in an "operational environment".

The CUTS platform, however, only achieved a success rate of 9% for identifying fruits and vegetables and 33% when a colour scheme was added in the specific 'kitchen laboratory' built to test the robot. Several key research challenges therefore remained before widespread commercial adoption could occur. These design challenges had among other things to do with perception, motion planning and software and hardware design, the researchers in KIT decided.

Motivated by previous work

They therefore decided to continue building on their previous work and applied for another publicly funded project, COOK. The COOK project was intended to solve the remaining challenges of CUTS, and commenced five months after CUTS ended. *"It is the next phase actually,"* Jannick said. In this sense, the COOK project started with both a narrative success story of the ability of designing an operational kitchen robot for cucumbers 20 years earlier at KIT and a robotic prototype from CUTS. For this reason, COOK has never had Technical Readiness Level (TRL) of 0. Originally, the COOK project was meant to have a duration of 46 months but now only two months remain and they may apply for an extension, because the developers have not managed to reach their objective yet. According to one of the roboticists, the robot from CUTS ended with a TRL of 6 - 7, and COOK is today *"more or less still in this phase"* (Jacob, CUTS coordinator, robot maker, SANDY). In order to get COOK ready for the market (TRL 9), the project needs more time and economic founding, the CEO from KIT concludes.

Since the prototype from CUTS, the roboticists have made ongoing changes in the design of COOK in order to improve its functionality and speed in handling mushrooms:

In research, you always have a prototype, which is big and has a lot of possibilities, and once you know how it should operate you can cut off these possibilities, and bring it back to essential things. This is the design process.
(Michael, CUTS coordinator, robot maker, SANDY)

In our project, we defined that we would have a basic system and an advanced system. And we are somewhere in between the two at the moment. So, our basic system with the robot is here, we used it in our previous tests.
(Jacob, researcher, robot developer, SANDY)

The design process is both described as a way *"to simplify"* COOK from the prototype from CUTS as well as making the robot *"more advanced"*. The changes made relate to the sensors in the gripping system, camera, and cutting system. It was only when they began testing the robot in the laboratory kitchen with other people moving around it, they noticed how humans functioned in the kitchen. They continuously made the robot stop working by reaching in front of its camera or sensors. This acknowledgement only came in the last phases of COOK. This paved the way for new innovative solutions as to where to place sensors and camera – and Paul, the CEO of KIT, now realize that the robot in its present form will never move to restaurants or private kitchens. And that some things could have been easier if the development had begun with working together with kitchen staff and real cooks to get a sense of their real work routines.

At the time of our visit, the second version of the advanced COOK robot was being developed. The robot was not operational for tests at the time of REELER's fieldwork, due to trouble in the design process. The team of roboticists waited for equipment to be fixed before they could continue the robotic work:

One of the equipment to maneuver it was broken, so we ordered a new one. So, we cannot operate it at the moment. It's a little bit, uh, unfortunate right now. But we are in between phases, and we are now working on the second, advanced robot.
(Jacob, CUTS coordinator, robot developer, SANDY)

The redesign has entailed a step backwards in the robot's TRL:

Michael: It takes you a little back from where you where, but we try to leap beyond that by making things more advanced actually, and [by] having these things like artificial intelligence go in there to detect the soil on the mushrooms better, to be able to decide and control like people do. [...]

Interviewer: Okay, so you are actually going a little bit back from this [CUTS] in readiness level, but you think that doing so, you will make it smarter in the end because you make it more advanced. Yes?

Michael: Yeah. Yeah, you have to mimic the human behaviour more and more.
(Michael, CUTS coordinator, robot maker, SANDY)

Thus, it is really difficult in non-linear development patterns to identify opportunities for starting with end-users. The kitchen robot began as a working prototype in an already defined setting, but ended in a different application and as a slightly less operational prototype.

(Based on interviews with Paul, robot developer, Michael, robot maker, and Jacob, robot maker, in the SANDY case.)

In at least two of the eleven case studies in REELER, the current robotics group was established on the basis of public funding for continued development of the same prototype. In both cases, the robot changed its name and a few specifications but the consortium was more or less the same. The main difference was in the scope of the projects. In one case, the first project would aim to help persons with bodily muscle impairment caused by genetic diseases. The second project would include a much broader group of patients that suffer from muscular impairment caused by more common factors such as traumatic injuries.

> *When conceiving this project, we took the value of technology developed in the previous project. But we also took basic information from the exploitation plan of that project, which was the idea that in order to become a commercial product, any system of this level of complexity requires a wide market. (…) A huge difference was that before it was dedicated to very serious but very rare pathologies. (…) This led us to changing many aspects of the project. And this is how we started conceiving the idea of the project we are working on now. (…) Everything has started from there, the entire idea of the project, including consortium members.*
>
> (Luca, physiotherapist, robot maker, REGAIN)

Another example of a publicly funded project that builds upon previous work is an autonomous agricultural robot. The very first idea for the robot emerged from previous robotic developments undertaken at a research institute. Fifteen years prior to the current project, that institute was involved in the development of a similar harvesting robot.

> *This was actually, I believe, one of the first robotic projects in this area on autonomous fruit harvesting robots. […] That is now fifteen years ago*
>
> (Espen, senior scientist, robot developer, SANDY)

These robot makers managed to successfully develop an operational version of a fruit harvesting robot. However, at the time the robot remained a research platform as the market was not ready for this kind of robots and there was no demand on the farmers side. The lacking demand well-illustrates the fact that being driven by the technology (or funding opportunities) instead of being end-user oriented in the very early TRLs, robotic projects may sometimes develop solutions that do not meet the actual robot users' needs. In fact, in several of our cases we see the robots were never at Technical Readiness Level (TRL) 0, 1, 2, 3 or 4. These design phases, were dealt with in connection with the previous robot worked on by the robot making teams and presumably not revisited. Thus, some developers may cycle around the same robot project, because they have not reached what was promised, and instead they seek funding for further development for several years in a row. We do not see this in the same way in companies which are more wont to move on to another type of robot.

REELER identifies two main risks following from this 'approach'. One is a research logic that does not emphasize the need for innovative robots to ever enter the market to contribute to solve the problems intended and to economic growth. The other is the risk of staying within only a narrow area of knowledge and networks of collaborations, with the main focus on technology rather than end-users and their needs. While such an approach may work well for robot makers, it may not necessarily be the case for end-users, who for long periods of time remain largely distant or excluded from the conceptualization and development process of the robot. Even from a design perspective, it can be a waste of time and money if the envisioned users are not included early on to avoid misconceptions and normative thinking about the users. However, from a robot maker point of view, it can be very difficult to know how to best involve users, because direct users and affected stakeholders are different and have different motives (which is why alignment experts are needed (*see 12.0 Human Proximity*).

> *It was not like the same people involved in the same project from start to end. It was different kind of cleaning assistants, different kind of IT nurses and so on, so that was not ideal. It is something that we really try to do now in the projects that we are doing, that we set this project team, also from the partner's side to make sure that they are committed and they are the right people that we have involved in the project.*
>
> (Samuel, product innovation manager, robot maker, SPECTRUS)

It is a lot of work for robot makers to involve users directly. The robot makers are often looking for consistent users that can over time align themselves with the development. When users are coming with new motives, developers spend time again on buy-in and bringing them on board.

Interviewer: And why is it so important that they are the same people?

Samuel: I think it's also something like satisfaction for them that they see that the value of their input and insights is something we actually use eventually. It's not something that they just have to participate in in a two-hour meeting and they don't hear anything about the project until maybe there's a product in three years. So, I think it's good for them and it sort of motivates them a bit more to be more involved in this process I think. So, I think it's good for them, but of course it's also good for us because then we have sources on all our data fragments from the projects and who gave that knowledge and then we can call that person again and ask again and they are well informed about the project and it saves time also for us, I think. So, it's just a matter of finding the right people and that's always a bit of a challenge, I think, for us.

(Samuel, product innovation manager, robot maker, SPECTRUS)

Many of the robots developed in customer-oriented design processes are created in areas where the developers may have little expertise and knowledge about the application's situated context. This entails a lot of collaboration in order to identify market opportunities – and in some cases user-needs and reactions to their robot ideas. However, in all REELER cases, the beginnings of new robot solutions are initiated by robot makers (robot developers, funding bodies, or robot buyers acting as application experts), and not by the potential end-users or affected stakeholders. While end-users who lack expertise in robotics cannot be expected to define the solution, they ought to be considered in defining the problem; however, as it stands, end-users' needs are brokered by intermediaries. Put differently, robot beginnings occur within the inner circle – the 'robotic bubble' of REELER's human proximity model (*see 1.0 Introduction and 12.0 Human Proximity*).

Clients or customers (like the director of a public hospital, a farming company, or a public transport company) may wish for specific robots and act as facilitators with the robot developers and in some cases application experts. Yet, the end-users and affected stakeholders, i.e. the people working in farming, hospitals and public transport, are generally involved only to test already developed ideas. Many affected stakeholders have very little knowledge of robots and what they can do for them, if developers were to communicate with them the potential of robotics, many stakeholders could (and have) come up with good ideas based on their expertise in their daily work. One example of this is a cleaning lady in Portugal, who suggested a robotic arm to remove the spider webs she cannot reach on her own (*see 11.0 Gender Matters*).

Another has an idea for a robot that can easily move a bed so she can clean beneath it without straining her back. A worker in a construction site would like a robot that helps speed up, not slow down, work. However, the question is not only whether a given robotics project start with end-users or is user-oriented, but also the priority given to end-users and their well-being (as opposed to the mere purchasing power). Across cases, we see this as an untapped resource for novel ideas in robotics that are well-defined in relation to the application area. Unless familiar technical beginnings and existing homogeneous networks are opened to affected stakeholders and their experiences, these resources may remain underutilized.

2.5 Concluding remarks on Robot Beginnings

Familiar beginnings breed familiar results. To truly be innovative requires heterogeneity and novel ideas. Where public funding is involved (in most cases), the return on investment must be fairly distributed. Design processes should thus be more inclusive, taking in persons with diverse motives. By bringing end-users and other affected stakeholders into closer proximity to robot makers – by expanding the interaction space (puncturing the robotic bubble), it might be possible to bring about some alignment between them. User involvement in robot beginnings is further hindered by robot developers taking their starting point in familiar people and existing technologies. This is complicated, however, by the distributed nature of robot development, both in terms of time and geography, but also in responsibility across organizations. Ultimately, if organizations are so motivated by making money as we argue in this chapter, it might behoove them to solve these problems of engagement with users, so that robot developers can go on pursuing their passions for robotics and doing good.