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Industrial innovation processes and societal challenges: How Telenor's mobile phone data became a tool for fighting pandemics

Magnus Gulbrandsen *, Erlend Osland Simensen

TIK Centre for Technology, Innovation and Culture, University of Oslo, Norway

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ABSTRACT

Processes of innovation and scientific breakthroughs are not linear, and their outcomes are notoriously difficult to predefine. This paper contributes with an inductive longitudinal case study of how industrial R&D and innovation activities in a multinational telecom firm contributed to tracking the spread of Covid-19, a societal challenge unrelated to the starting point of the firm's relevant R&D. After twenty years, insights and methods from network analysis using call detail records of mobile phone users eventually ending up in the pandemic response toolbox. We find that the process was dependent upon prolonged activities of key individuals in the firm, serendipitous meetings between people with common interests, and space and support in the organisation for activities with an uncertain effect for the company. The shift from commercial to public health goals was a process of exaptation, and later scaling up was tied to the emergence and perception of Covid-19 as a major societal challenge, which also helped deal with complex issues like privacy to generalise the use of mobile phone data for handling pandemics. This played out over three distinct phases of experimentation, exaptation and scaling up.

1. Introduction: processes in industrial R&D and challenge-oriented science and innovation policy

Industrial research and development (R&D) and innovation represent several parallel and complex processes tied to the production of knowledge, its transformation into various artifacts, and attempts at linking these artifacts to needs and demands in society (Pavitt, 2006). R&D and innovation processes are not sequential and orderly, they are most often messy and long with convergent and divergent events, and the outcomes may differ significantly from initial intentions (Van de Ven et al., 1990; Garud et al., 2013). The literature on such processes tends to analyse how certain outcomes emerge, using terms like multiple-level complexities, serendipity, exaptation, and preadaptation (Cattani, 2005; Garud et al., 2013, 2016a, 2016b; Andriani and Kaminska, 2021). These terms convey the limits of traditional planning and management, which is not least a challenge for science and innovation policy that seeks to harness research and innovation to solve societal challenges. But how do the extensive processes of industrial R&D and innovation end up as societally relevant solutions? This is the question we seek to answer with an analysis of a long-lasting process with industrial R&D and innovation at its core.

Challenges or even "grand challenges" has been a framing and fundamental aim in policies and practices of science, technology, and innovation for decades (Kallerud et al., 2013) tied to deeply embedded problems in areas like health, energy, food, the environment, and economic and social development and security. Many challenges are open-ended, large-scale and without simple solutions (Nelson, 1977), requiring sustained effort over time by many stakeholders to achieve necessary changes (e.g., Kuhlmann and Rip, 2018; Schot and Steinmueller, 2018). Some authors use a grand challenge framing to encourage new directions in policies and funding (Bogers et al., 2020; Kuhlmann and Rip, 2018; Mazzucato, 2018). Other authors use empirical cases and theoretical reflections to make suggestions for how private firms (Bogers et al., 2020; Ferraro et al., 2015) and public organisations (Kattel and Mazzucato, 2018) can address grand challenges in their activities. Challenges provide a decision-making heuristic to efforts to give innovation activities a specific direction (Edler and Boon, 2018). Explicit "directionality" may be seen as necessary to deal with urgent societal problems, to introduce a social purpose to activities involving science and technology, and to make priorities in policymaking and business strategies.

However, there is a clear tension between these aims and the

* Corresponding author.
E-mail address: magnus.gulbrandsen@tik.uio.no (M. Gulbrandsen).

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emerging empirical and conceptual process literature that underlines the contingent, experimental, and capricious nature of science and innovation (Pavitt, 2006; Garud et al., 2013, 2016a). For example, serendipity – accidental and unexpected discovery – is very common in all processes of knowledge production (Yaqub, 2017; Garud et al., 2016b). Any effort to address a specific challenge can give rise to unexpected results that are possibly relevant for another purpose. Similarly, the most relevant technologies and innovations for a specific challenge can come from an unexpected source. The matching of industrial knowledge production and artifacts with societal needs can be tied to concepts like scaling up and diffusion (e.g., Pavitt, 2006). Scaling up, diffusion and institutionalisation – which may be seen as part of a process of *generalisation* – of local experiments and solutions, are often found to be major bottlenecks in innovation processes (e.g. Wigboldus et al., 2016; Sengers et al., 2020). There is a general need for more investigations of how innovations "scale up" or in other ways become potential and realised solutions for grand challenges. We argue that the industry side, and industrial research and development (R&D) in particular, requires special attention in this generalisation process. It is often overlooked in grand challenge studies even though industrial R&D, given its size and problem-solving orientation, may be an essential element in finding and generalising solutions. This is not merely a small empirical gap but offers opportunities for improved theoretical understanding of how R&D and innovation processes over time can scale up and diffuse far beyond the intentions and needs behind putting these processes in motion. There are furthermore few links between the science policy literature and the detailed analyses of innovation processes, where we seek to make a clear contribution.

Empirical investigations have shown how industrial innovations developed for one specific purpose or function have found completely different uses later through a process of *exaptation* (e.g., Andriani and Kaminska, 2021). This is not least the case for medical devices and vaccines tied to the COVID-19 pandemic (James et al., 2022; Yaqub et al., 2022). Our longitudinal case is taken from Telenor, a major international telecom firm, which through different partnerships has started to implement big data approaches and network algorithms using their call detail records (CDR) to help understand and prevent the spread of epidemic diseases. Even if this result is a major source of pride for the company, not least its efforts in poor countries like Bangladesh and Pakistan, the starting point of the R&D was not at all public health or any other grand challenge. The link between the core idea and the grand challenge of pandemics only became apparent after a long and muddled process with multiple attempts at scaling up and diffusion.

Our inductive case study is oriented at exploring the characteristics of the process in Telenor and its partnerships from which the pandemics-use of call detail records emerged, thereby studying how R&D and innovation processes were tied to the scaling up of an innovation for a major societal challenge. We also make some practical suggestions about how industrial R&D can be harnessed in science policy attempts at generalisation of possible solutions for societal challenges.

2. Processes of innovation and industrial R&D and their link to grand challenges

Our theoretical section outlines key perspectives and findings primarily from literature on innovation processes that will be useful for an analysis of a case from the R&D department of a large firm, and we discuss how this literature can be tied to grand challenge perspectives in contemporary policy. Innovation is often seen as a vital activity for finding solutions to societal challenges and has become an important policy area in most of the world (Fagerberg, 2006). Many investigations of innovation adopt an evolutionary perspective, seeing it as a phenomenon that can be usefully understood through concepts from a Darwinian natural history perspective (e.g., Nelson and Winter, 1982).

2.1. Innovation processes, serendipity and scaling up

In the theoretical and empirical literature about how innovations emerge and evolve, innovation processes typically refer to "the sequence of events that unfold as ideas emerge, are developed, and are implemented within firms, across multi-party networks, and within communities" (Garud et al., 2013:774). The word process is often pluralised because it can have different types and vary with the wider context. A core activity is the long-term matching of ideas or technical practice with needs and demands, which can be tied to three partly overlapping processes: knowledge production, translation of knowledge into artifacts, and responding to and influencing users' requirements (Pavitt, 2006). This can take a lot of time, not least because firms rarely can define the range of possible uses of their innovations (ibid.). Innovation processes are therefore complex objects of investigation, and many of the early and influential analyses were found in books rather than articles.

Allen's (1977) classical study of science and engineering organisations showed that ideas often spread through informal and unplanned contexts, highlighting the importance of certain individuals termed "gatekeepers" for bringing external knowledge into the organisation. Later studies have also stressed the centrality of individuals, personal contacts, and collaboration both within the organisation and with external actors, not least because a lot of the knowledge involved in innovation is tacit (Pavitt, 2006). The so-called "Minnesota studies" of 14 long-term innovation processes (Van de Ven et al., 1990) highlighted the dynamic and unpredictable nature of how events unfold and how collaboration networks change over time. This finding is also echoed in later investigations of impacts of R&D (Joly et al., 2015) and emphasised in newer innovation process frameworks (Cattani, 2005; Garud et al., 2013, 2016a, 2016b). Such frameworks do not necessarily distinguish sharply between the emergence of an innovation and its diffusion or scaling up, because they may be seen as partly overlapping activities within a longer-term process of knowledge development and exploitation.

A common theme in recent articles on innovation processes is how a specific technology or other body of knowledge finds a significant use that was not anticipated when the technology was created. Like the more general innovation literature, evolutionary references and metaphors are plentiful, notably Steven Jay Gould's concept of *exaptation*. This was initially used to describe how birds can fly with feathers that were initially developed for insulation – not because feathers were "adapted" to a new situation but because a new use was "discovered". Gould thereby criticised functionalistic and deterministic interpretations of evolution in nature, and many of the contemporary writers on innovation processes criticise simplistic management and policy perspectives.

Using extensive historical data, Cattani (2005) showed how existing knowledge tied to glass production became valuable for developing fibre optics, even if that application was not at all perceived by the key experts. Another wide-ranging historical case study employed exaptation to analyse innovations from coal tar and how they opened completely new areas of use that were not thought of at the time of knowledge creation (Andriani and Kaminska, 2021). Garud et al. (2016a) tie exaptation to pools of knowledge, events where people from different pools are brought together, and forums when the relationships between such individuals persist over time. These concepts have been used to explain how new medical devices emerged as a response to the COVID-19 crisis (James et al., 2022). Here and in more conceptual writings, exaptation becomes an important third method of discovery next to "technology push" and "market pull", and a fresh perspective on serendipity or the balance between "luck" and "foresight" (Andriani and Cattani, 2016).

Much of the process literature also discusses serendipity, mostly seen as "happy and surprising accidents", which is well-known from the literature on science both tied to the discovery of new phenomena and

the discovery of new applications of scientific knowledge (Merton and Barber, 2004). A recent theoretical framework (Yaqub, 2017) identifies four different types of serendipity in science: targeted search solves an unexpected problem, targeted search leads to a solution via an unexpected route, untargeted search solves an immediate problem, and untargeted search solves a later problem. All of these are processes tied to theoretical anomalies, the talents of individuals, a tolerance of errors or ambiguity, and knowledge networks (ibid.). Such networks can link people and groups representing discoveries or solutions with people representing problems and opportunities for exploitation and generalisation.

Serendipity is not just relevant for understanding processes in scientific work; the scaling up and generalisation of radical innovation in large firms "appears to be almost capricious" and "dependent on chance events" (O'Connor and Rice, 2001). Garud et al. (2016b) used the case of the 3 M Post-it notes to develop a theory of innovation processes that are "full of serendipitous events" (p. 452) driven by interpretations of an idea's potential. This does not mean that managing potential innovations should be left to chance, and the literature generally speaks of "improving the odds" through network reconfigurations (O'Connor and Rice, 2001), performative action (Garud et al., 2016a and b) or institutional leadership and management of part-whole relations (Van de Ven et al., 1990).

As in the more general process and serendipity literature, the role of individuals is highlighted in various ways. For example, recognising opportunities for more radical innovations in large firms rarely depends upon market signals but instead upon individual initiatives and capacity mostly from low and mid-level research managers (O'Connor and Rice, 2001). There is a high risk that an innovation project will be killed or shelved unless new people enter the process, who often become involved through the personal networks of key individuals. A common pattern is "senior management behaving as a protector within a resistant organization, and lateral networks providing resources … and confirmation of the value of the opportunity" (ibid. p. 108), unless the project can get a senior manager to grant protection from conventional forms of evaluation. In addition to the importance of longer-term employment, many innovation process studies of large firms highlight external partnerships particularly with universities and other scientific organisations (Pavitt, 2006).

Even if innovation processes are characterised as non-linear and influenced by chance events, many authors still frame scaling up, translation or generalisation as happening in phases or stages. O'Reilly and Binns (2019) argue that for firms to develop disruptive innovation they must master three stages of the development process: ideation, incubation, and scaling. The latter phase is deemed notoriously difficult as it demands extensive alignment of resources and timing to enter a relevant market or application. Garud et al. (2016b) argue that different actors operate in different time scales and that perceptions of relevant outcomes change over time, which means that innovations and their generalisation can be seen as too early or too late. More fundamentally, even if a company allocates large amounts of time and resources, many innovations will fail for various reasons (Van de Ven, 1986).

2.2. Grand challenges and industrial R&D

Turning to grand challenges, health is a major example here with many facets such as avoiding unnecessary health-related suffering, ensuring fair healthcare services for all including preventive medicine, and reducing the spread of communicable diseases. U.N. sustainability goal number three – "Ensure healthy lives and promote well-being for all at all ages" – explicitly ties health to the fundamental aspiration to a sustainable future. A pandemic such as the one caused by Covid-19 is arguably a grand challenge, a notion that is shared in a wide selection of academic literature (see e.g. Bertello et al., 2022; Kokshagina, 2022; Howard-Grenville, 2021). Although some solutions to health-related challenges can involve civil society and engaged stakeholders and be spread through digital platforms and social networks (Von Hippel, 2015), outbreaks of severe communicable diseases like Covid-19 may require more intensive efforts involving joint efforts across sectoral and technological borders (Chesbrough, 2020). Connecting industrial R&D to ethical and societal aspects has been found to have multiple benefits for firms (Flipse et al., 2016), in addition to the obvious societal benefits.

A grand challenge emphasis is, as discussed briefly in the introduction, most often tied practically and conceptually to policies and strategies that have strong intentionality and directionality, i.e. the end goal is clear and provides a direction for research and innovation efforts and their management (Edler and Boon, 2018; Kuhlmann and Rip, 2018). What the process literature highlights is that many important innovation processes are not tied to adapting existing technologies to specific demands, but rather to the maintenance of heterogeneous knowledge bases that may find new uses through exaptation.

We are interested in looking in detail at how the call detail records of a major telecom firm found their way into various pandemic models through R&D and innovation processes that lasted a long time. Much of the process literature referred to in this section has looked in particular at the initial stages of exaptation (e.g. Andriani and Kaminska, 2021). Our case adds to the literature by analysing how a long-lasting societal effort in an industrial R&D department was scaled up to provide a seemingly immediate solution for an emerging grand challenge (cf. Bogers et al., 2020). Ideas like exaptation and serendipity signal that there is a disconnect between problems and solutions, and that there are various ways in which they may converge (Garud et al., 2016a). Our brief literature review oriented at process perspectives has provided some additional starting points for what to look for in a complex longitudinal data set such as the role of individuals, external partnerships and top management support.

3. Context, case, and method

To understand how persistent activities of industrial R&D and innovation end up as societal solutions, we opted for a longitudinal case study design like a lot of other empirical work using process theories.

3.1. Research context and defining the case

The case emerged in a research project on impact pathways from industrial R&D in a large multinational firm. We mapped its core knowledge bases and found that there was significant competence on network analyses and big data which seemingly had seen several impact pathways. We selected one of them – the application of network analysis to understanding movement patterns during a pandemic – for the analysis reported in this paper.

Telenor, the firm from which the case originates, is a large multinational telecommunications company active in nine countries in Scandinavia and Asia and with more than 20.000 employees. It has around 200 million mobile phone subscribers, and the company has evolved from a state-owned monopoly to a publicly traded multinational corporation after the Norwegian market was deregulated in 1998. The research part of Telenor was founded in 1967 as a semi-external research unit that played a central role in developing several important and widely adopted technologies like GSM, and in making Norway the world's first country to have a fully automated phone system. This R&D unit was later dismantled and then restarted and reorganised several times.

Telecommunication companies have access to call detail records (CDR), which are useful for analysing networks and movements of people. CDR data includes timestamp and GPS locations of all subscribers and can therefore give precise information about people's location, communication patterns and movements. For analysis of how diseases spread, the aggregated data can be used to study the mobility of people during different temporal periods, such as commuting to work, holidays and seasonal migration (Grantz et al., 2020). Telenor has access

to a lot of such data as a mobile phone operator in several countries.

Our case is defined as the activities of Telenor R&D in network studies based on CDR data that later became used for global health purposes, culminating in the implementation of these data into the Norwegian health authorities' epidemic model at the outbreak of COVID-19 in March 2020. We do this as a tracing backwards historical case study, common in studies of impacts of R&D (cf. Donovan, 2011; Joly et al., 2015). More fundamentally, our approach follows an inductive qualitative approach (cf. Merriam and Tisdell, 2016), aiming for the narrative of the case to emerge from the data rather than from pre-conceived concepts and constructs. The timeline, going back to the beginning of the 2000s, and the inclusion of all the company's partnerships directly related to mobility data, constitute the boundaries of the case (Stake, 2005). The case represents how the contribution to solving a grand challenge was made possible through long-term research and innovation processes, and it also shows that most of the attempts at generalisation – in our case diffusion to policy and scaling up of use of CDR data – failed. Many of the key events in the innovation process were unplanned or happened by chance.

3.2. Data collection

We sought to understand the origin of the specific competence building within the industrial R&D organisation as well as the series of important events that followed. Since this has been an explorative and inductive single case research, we adjusted our approach as we uncovered findings and main events.

We started by interviewing personnel that had been involved since the beginning of our timeline in 2001 – the first attempt to "do research on" mobility data – and moved on to key collaboration partners and other central individuals. These included key researchers from Telenor Research, a user partner from Telenor Pakistan, two academic research partners in collaborative health-oriented research projects, and a representative of a public health organisation who was involved in the Bangladesh pilot studies and the implementation of the mobility model for Covid-19 in Norway. The informant selection followed a classic snowball sampling method (Parker et al., 2019) and the work was done between May and September 2020. In September 2021 we added seven more interviews with previous top managers in the company that had all been formally involved in managing the R&D department in various ways. This was carried out to understand the wider context in the company and whether the events were part of a strategy or if top management was involved in other ways.

The interviews lasted between 35 min and 1 h and 26 min, with half of them longer than an hour and only two shorter than 50 min. All interviews were transcribed and uploaded to the qualitative analysis software NVivo for coding and analysis. To remedy biases connected to retrospective narratives, documents were used to confirm or revise the timeline of events. In this regard, both output data such as publications and patents and internal meeting notes were useful for triangulation. Table 1 lists the additional data that was actively used for the timeline, although the access to internal documents were much wider than the ones listed here. Table 2 lists the informants used for the case, informant 1 was interviewed two times and we had numerous formal and informal discussions with number 14 (a key project coordinator in the R&D department)..

3.3. Data analysis

Both authors read all the interview transcripts and other documents, which we first used to make a timeline of the case that we also validated with key interviewees. Interviews were also coded for main themes not specifically tied to the work in this paper. To strengthen intercoder reliability, we followed suggestions in the methodology literature (O'Connor & Joffe 2020) and had several meetings and reflexive discussions to ensure a high level of agreement on how to understand interviewee statements and derive more overarching themes (axial coding) to the process perspective in this paper. This mostly consisted of merging or expanding themes, for example through realising that many of the statements about chance (serendipity) also contained statements about new opportunities, or that collaboration was closely related to talk about experimentation. Table 3 outlines the codes. A list of "typical" statements is difficult to make from the rather small and specialised group of interviewees, but we have included axial codes to the quotes used in the next section (some quotes contain several codes) to indicate how the quotes fit our analysis. The coding was also important for providing insights into how to interpret the main events emerging from our construction of a timeline.

Table 1
List of documents and meetings connected to the case used primarily for triangulation.

Type of documents	Details
Published research papers	Wesolowski, A., et al. (2015): *Impact of human mobility on the emergence of dengue epidemics in Pakistan.* doi:https://doi.org/10.1073/pnas.1504964112 Chang et al. (2019): *Mapping imported malaria in Bangladesh using parasite genetic and human mobility data.* doi:https://doi.org/10.7554/eLife.43481 Engebretsen, S., et al. (2020): *Time-aggregated mobile phone mobility data are sufficient for modelling influenza spread: the case of Bangladesh.* doi:https://doi.org/10.1098/rsif.2019.0809 Riedl, C., et al. (2018): *Product diffusion through on-demand information-seeking behaviour.* doi:https://doi.org/10.1098/rsif.2017.0751 Jin, C., et al. (2019). *Emergence of scaling in complex substitutive systems.* doi:https://doi.org/10.1038/s41562-019-0638-y
Other documents	https://www.biginsight.no/ - website for the research centre on big data that Telenor was part of. Start of collaboration with Norwegian Institute of Public Health Patents by Telenor and relevant employees Project administration documents about social network analysis in Telenor Customer data analytics presentations (based on social network analysis) Yearly reports Telenor 2001–2021
Meetings with Telenor	08.09.22: meeting at the university with Telenor's R&D department 31.08.22, 02.09.21, 30.06.21, 23.11.20 and 24.06.20: leadership meeting Telenor Research with presentation and discussion

The main timeline of the case is summarised in Fig. 1. SNA is an acronym for social network analysis and FHI is the Norwegian Institute of Public Health. The next section will go into more detail on the phases and events of the case.

4. Phases and events of the case

We find it relevant to distinguish between three main phases of the research and innovation activities: competence-building, academic collaboration and thematic reorientation, and the generalisation of public health models. This is also included in Fig. 1, and we describe events in each phase in detail in the rest of this section.

4.1. Competence-building

In the first phase from around 2001 to 2010, the most important groundwork was laid for use and access to data. Three newly employed researchers with backgrounds from physics, mathematics and anthropology met in 2001 and found a common interest in the emerging field of network studies and the use of call data. The very origin was described as a chance meeting:

Table 2
Summary of informants to the case. Length is hours:minutes.

	Informant	Position	Date	Type	Length
Interviews related to the case	Researcher 1	R&D department Telenor	25.05.20	Video call	1:21
	Researcher 2	R&D department Telenor	18.06.20	Video call	1:26
	Telenor 3	CSR department Telenor	31.08.20	Video call	0:49
	NIPH 4	Norwegian Institute of Public Health	18.09.20	Video call	0:36
	Academic partner 2	Researcher 1 US	11.09.20	Video call	0:42
	Academic partner 1	Researcher 2 US	22.09.20	Video call	0:52
Interviews with leadership about industrial R&D strategy	7	Former senior executive, group + Leader R&D department	21.09.21	Video call	0:50
	8	Former senior executive, group + Leader R&D department	27.09.21	Video call	1:02
	9	Former senior executive, group	28.09.21	Video call	1:16
	10	Former senior executive, group	29.09.21	Physical	1:17
	11	Former senior executive, group + Leader R&D department	18.10.21	Video call	0:52
	12	Former R&D department Telenor	30.09.22	Video call	0:48
	13	Former R&D department Telenor	05.10.22	Video call	0:55
	14	Former R&D department Telenor	Several times	Physical	1:00+

Table 3
Coding of interviews.

Thematic coding	Axial coding
- Chance	- Chance/opportunity
- Anticipation/expectation	- Anticipation/investment
- Vulnerability	- Collaboration/experimentation
- Ethics/privacy	- Vulnerability/ethics
- Collaboration	- Reorientation
- Opportunity	- Generalisation
- Investment of own time	
- Grand challenge	
- Abandonment of diffusion	

"He [one of the researchers] approached us [the two others] and we sat in some peaceful, sunny place there, in the cafeteria, and he said: Let's do social network analysis. Just like that. […] And we thought we had a unique opportunity because of sitting on this all this telecom data" (Researcher 2; chance/opportunity, collaboration/experimentation).

Their first experiments were tied to studying their own personal network, leading to the development of some novel centrality indicators and a sense that the work "would prove important in the long run". It was unclear in the beginning what the mandate or purpose of the activities in network analysis were: "I don't know if it was officially a project or not. But … it didn't really cost any money, it just cost time... they [management] let us spend time on it" (Researcher 2; chance/opportunity, collaboration/experimentation).

Scaling up the research from the first group-internal experiments proved difficult in Norway due to concerns about privacy regulations. The next step was to access, clean and analyse a call graph of almost eleven million customers from a Telenor subsidiary in Eastern Europe where the privacy rules were less strict. This led to a series of attempts at creating economic returns in many of the company's subsidiaries, for example through increased knowledge about customer behaviour and evidence based viral marketing, which largely failed in the scaling up phase even if initial experiments were promising. Many of these attempts were based on ideas from chance meetings (i.e., meetings that did not directly concern use of the new network-based ideas) with individuals in business units primarily in Eastern Europe. One of the largest challenges at the time was to aggregate and clean large datasets for models, as memory and software for handling such data was still underdeveloped.

Privacy and security, emanating from the semi-public nature of mobile phone data (often tied to operating licenses) and different national legislations, were seen as troublesome. The opportunities for legally using Eastern European data in a way that would have been illegal in Norway contributed to mixed feelings in the team. Although the information was anonymised for the researchers, they found it too risky to "go public with this kind of data" at the time and kept all work in-house, even if they later realised that they were several years ahead of the leading academic research in the area. "We basically did everything ourselves, we almost didn't dare to talk about it externally… if we had published on this [at the time] it would have been two years ahead of the key CDR paper [Onella et al. 2007]" (researcher 1; vulnerability/ethics, anticipation/investment).

Between 2003 and 2008 they registered eleven patents tied to insights into social networks, and Telenor formed a spinoff company together with key employees with an aim to commercialise the technologies. The patents concerned search technologies, and the idea built on the patents was to profit from using network analysis principles such as page ranks to create search engines that could challenge Google and others. Telenor released the patents and sold the stocks in this spin-off company after a difficult period following the financial crisis in 2010 (the company still exists as of 2022, offering specialised services to a few industries).

As mentioned, one of the first 'problems' that this 'solution' aimed to address was targeted marketing for mobile phone customers, first tested out in an Eastern European business unit. The researchers saw this as a success both innovation-wise and economically, but the effort was shut down following a change in contact person: "[What we did there] is an example of the amazing things that can happen with the right contact person … and then it stopped when we got a new one because it didn't further his career to be involved." (Researcher 2; vulnerability/ethics). A representative of the management team at the time stated that learning from the R&D had been difficult even with promising results:

"We had a customer who was terrible at paying his bills, so he was thrown out of Telenor in Hungary. And then the … R&D people's analysis showed … that this was a person who had an enormous network where many people phoned each other." (Interviewee 10; generalisation).

This interviewee explained how the potential of such findings relied on very intense communication work by the research staff, which was not always successful. Dependence on the goodwill of key external contact persons was also a recurring theme in the interviews and in the various stages of the development of different forms of social network analysis. Similar experiments were launched in different Telenor business units in other countries. But even with some promising viral marketing experiments, the results were difficult to transfer to other parts of the company and there seemed to be few mechanisms in place to

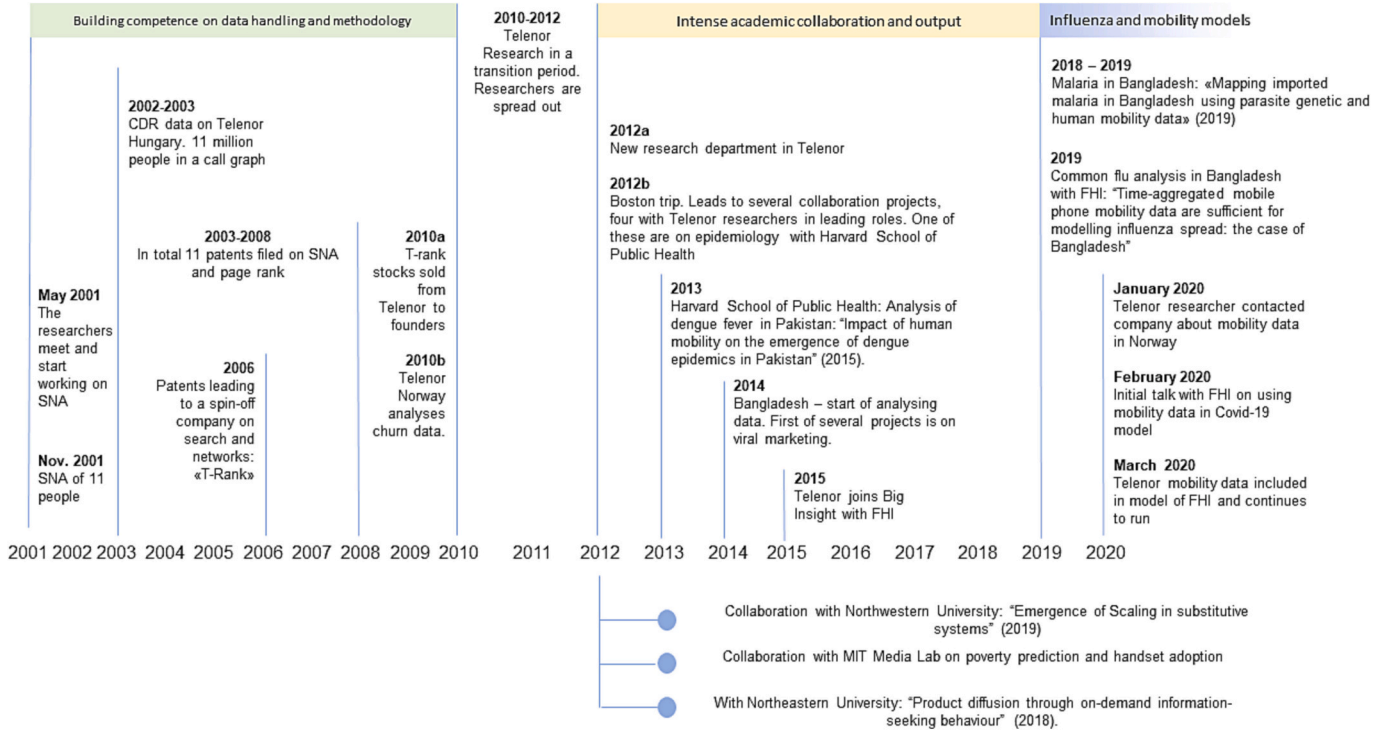

Fig. 1. Timeline of events.

continue to build on experiments and experiences when these met existing priorities and routines:

> *"It's never been standardised. We've had successes in several countries. But in each new country we had to start all over again. … Well, we tried to standardize it. … And there was so much politics that it kind of fizzled out." (Researcher 2; anticipation/investment, generalisation).*

Thus, generalisation in this first phase was a series of efforts aimed at making profit for the firm. It led to minor and short-lived outcomes, and the attempts at adaptation and scaling up became dependent upon support of individuals in various parts of the large organisation. This support tended to fizzle out when people changed positions and priorities shifted.

4.2. Academic collaboration and thematic reorientation

In 2010 the social network activities went into two years of hiatus following drastic cuts to R&D budgets. Key researchers did not leave Telenor but worked on various projects in other parts of the company. The company relaunched its R&D unit in 2012 and all staff members became collocated in the head office facilities. This was a boost for R&D, not just with larger budgets, but a consolidated unit in one place meant more time and infrastructure for doing dedicated research activities.

The most important change was the development of strong new ties to the academic community and the move into the area of public health. A study trip to Boston, the result of an invitation from a leading U.S. researcher that one of the Telenor researchers had met at an earlier conference, became a turning point for their work the next eight years. In Boston they met several world-leading research communities on social network analysis and epidemiology at Northeastern University, Harvard School of Public Health, and MIT Media Lab. This sparked several collaborations that later resulted in major new uses of CDR data and the publication of important scientific papers. Researcher 2 recalled the meetings in Boston:

> *"[W]e just felt like kids with money in a candy shop. There were hundreds of top researchers. Eager to collaborate with us because we had data. … And then we started four different [research] threads, [with one of us as] manager for each of these … threads." (Researcher 2; collaboration/experimentation; chance/opportunity; reorientation.*

The initial meeting may have been serendipitous. But the combination of the call detail records data in Telenor and the competences of their research unit, signalled through participation in academic conferences and communities more than in open publications, seems an important precondition for what came later. Even if many interviewees mentioned chance meetings, Manager 4 (former head of R&D) stated that the visibility of the R&D work had been important as it "leads to expressions of interest … because [people in the system] know about us and see us". An external academic partner stated:

> *"I viewed telco data as one of the most promising types of data for understanding human society, but by definition it required collaboration with a telecom firm. So when I saw [Researcher 2] [in the elevator at a social network conference], I told him I'd worked with that kind of data and would be interested in a talk. We exchanged business cards and later I came to Oslo and we started a formal collaboration" (Academic partner 1; chance/opportunity, collaboration/experimentation).*

Formal partnerships were established (not contract research), and the collaboration with Harvard School of Public Health was still ongoing first half of 2022. A professor said that their epidemiological models had gaps, which mobility data could fill, especially for highly mobile populations or in regions with seasonal movement patterns and asymmetric movements. The basic need was because "movements spread epidemics, and [CDR data] can help you make surveillance systems". This professor had worked with other telecom firms earlier, but saw the collaboration with Telenor as different, partly because of the competences in its R&D unit and partly because of its large business units – mobile phone operators – in countries with severe malaria challenges, which made it easier to keep data sufficiently secure:

> *"[It's] much simpler when these operators are part of the Telenor group, and easier scientifically with somebody [from Telenor Research] to translate. The data doesn't actually leave the country, it stays in Grameen*

in Bangladesh and so on. There is an additional layer of security around, and there is trust because there is a corporate structure" (Academic partner 2; chance/opportunity, vulnerability/ethics).

While the company had made several attempts to commercialise its social network research, the academic partners assumed that the company was involved not for "publicity stunts" but for "social responsibility reasons", and that its autonomous business units had an incentive for this. Another external academic partner had similar experiences with the enthusiasm of the industrial partner, but said that it was very dependent upon individuals:

"I observed the challenges Telenor has with its [international] business units, because the latter are very independent. [To do this type of research and innovation] they need someone from the business unit with a huge personal interest that can carry the flame. I've seen it in other large, decentralised companies as well, that R&D collaboration is essentially voluntary, which means that it often does not happen. But we made it because we had a local representative that was… willing to spend a lot of own time on it, and a management person who provided some resources. … So you need multiple champions, we had them in Oslo but you need them in a lot of other places as well" (Academic partner 1; vulnerability/ethics).

The first epidemiology-oriented project (2013) used data from Telenor's subsidiary in Pakistan to analyse the spread of dengue fever. The team used mobility patterns to see how dengue fever had been spread from the hot and humid south to northern parts of the country. To implement the model and use the data from a foreign country, the team had to overcome several privacy and security barriers, including sharing data with academic partners in the U.S. and limiting the use of the data to public health purposes:

"It was essential to figure out what was possible from a regulatory point of view, could we share these data with Harvard? For CDR this was not possible, the data could not be moved over the border, but they could be used for public health purposes, at least at the time. But there was no precedence for such a project, and we were willing to take that risk" (Telenor 3 CSR representative; vulnerability/ethics, anticipation/investment).

The main solution was that the team had to travel to Pakistan to do the complete analyses locally and finish the entire process from gathering and cleaning data to the core results, to avoid sending the data out of the country. The results confirmed that their model with CDR mobility data predicted the spread of the disease better than all existing models (Wesolowski et al., 2015). Although the methodology turned out to work well, it was never implemented by the Ministry of Health in Pakistan although it gained some local interest through a partnership with Peshawar University. The reason for a lack of wider diffusion seemed to be difficulties in convincing the local government to continue to run the model, which was tied to fear of losing jobs and tasks to new technology and to competences and capacities more broadly:

"Human capacity is a big [constraint]. This approach is not trivial, methodologically, in a lot of places they don't have the capacity, they don't have the people that are trained in this type of data science and modelling. … In some countries more than others [there are] also regulatory and privacy issues" (Academic partner 2; vulnerability/ethics).

In 2014, the research team teamed up with Northeastern University to study viral marketing with data from Telenor's business unit in Bangladesh. Again, an important contact person in the business unit made collaboration with the research unit based in Oslo possible. Several follow-ups within epidemiology then happened in Bangladesh, where different teams used the established contact, data, and the acquired competence from Pakistan to track outbreaks of malaria and the common flu. The Ministry of Health in Bangladesh was involved in the malaria study from the beginning through co-writing two publications, which according to Telenor staff made implementation easier. However, gathering the required funds for the data and for running the project over time became another barrier for continuing the models after the research project ended. The local champion was also lost when the employee got promoted to another business unit in another country. Again, the academic impact from the epidemic case was substantial with papers on a new model of the spread of corona type viruses published, but the researchers expressed concerns about lack of societal impact and diffusion even if the projects were "nice academic exercises".

Barriers to implementation and diffusion were as mentioned tied to complex issues such as privacy and ownership of data related to national security interests, but resources and competence building also figured in all interviews and in several of the archival documents. The academic partners expressed that a major challenge to such generalisation attempts could be the way in which collaborative research projects and related training activities are carried out, with few incentives for capacity building and local training related to public health:

"Capacity building [in the relevant country/region] is key, but you're not at all incentivised for that. It's a time sink. You do something for a week but then you've ticked that box. How we train people in public health is a major barrier to sustaining these types of innovations" (Academic partner 2; anticipation/investment, vulnerability/ethics).

In this phase, the main outcome was a switch away from commercial uses of the network data and algorithms towards public health applications, even if some attempts were still made (not successfully) to find uses with clearer direct benefits for the company. This exaptation was driven by the researchers' professional interests developed in wider international academic partnerships rather than any explicitly expressed ideas about solving societal challenges (even if they were implicit). Again, attempts at adaptation and scaling up became difficult because they relied on vulnerable networks with individuals in user settings.

4.3. Generalisation of public health models

For the interviewees, the Covid-19 pandemic represented a turning point, a global crisis that suddenly made mobility data widely recognised as valuable beyond specialised audiences. In the last week of January 2020, as Covid-19 started to spread throughout the world, a Telenor researcher confirmed that the company had the necessary data for making a mobility model in Norway and set up a meeting with the Norwegian Institute for Public Health. They had been an earlier project partner related to using CDR data for the common flu, which for privacy reasons was carried out in Bangladesh. The influenza virus spreads in a different way than dengue fever or malaria, which meant that the validation of a flu model in Bangladesh in this earlier project had paved the way for the models for the similar Covid-19 pathogen.

Before the end of February 2020, the institute for public health had a model up and running with mobility data from Telenor, and the model is still (at the time of writing in late 2022) updated every week. The implementation or generalisation of the model in Norway was thereby made possible by the previous experiences in Bangladesh, which was again made possible by the knowledge built up in the company's extended social network community through academic work and site work particularly in Pakistan and Bangladesh, which again built upon the European social network analyses from almost a decade earlier:

"[W]e tried in Pakistan, and we tried in Bangladesh, and in the end, we made it in Norway… I do not think it would be easy to do this if we did not have the experiences from the projects in Asia. Because it gave us confidence on how to handle privacy aggregation and how it should be processed. At the same time, it was important that there was research collaboration in Oslo that already existed." (Researcher 1; reorientation, generalisation).

The final implementation and the highly visible work on dengue fever and malaria was a source of pride in the retrospective interviews

with managers. Manager 2, who left the company before the main results in public health, found the related competence important, "this competence that for some strange reason has been maintained for more than 20 years" (chance/opportunity). What the results imply for the firm was still under debate:

> *"If you take this example, it's clear that we haven't gotten anything. I mean it hasn't generated any money for Telenor, but it has generated attention and contributions to society. And that's something … we're proud of, but I don't think you'll find contribution to society in the key performance indicators of the research department. But maybe it should have been." (Interviewee 11; generalisation, anticipation/investment).*

In this third phase, generalisation happened by making CDR data an integrated part of models of the spread of Covid-19, with Telenor providing new data weekly. Many of the technical and practical challenges had already been dealt with in earlier work on other diseases, so adapting the data and related methods to the new pathogen, was not complicated. Covid-19 was a clear and visible challenge, also in the general media, which served to reawaken sleeping professional networks and provide a strong impetus for scaling up solutions and putting them into practice.

5. Discussion

What does our case tell us about innovation processes in large firms and how they may become relevant and scaled up or generalised to meet societal challenges? The core innovation or idea was the development of mathematical algorithms and related software and data handling procedures to capture value from information containing the geographical location and movement of all individuals with a mobile phone subscription. This was initially not related to its final use for public health purposes, which makes it a case of exaptation (Garud et al., 2016a; Andriani and Kaminska, 2021; James et al., 2022). The relatively quick turnaround in a public health direction was similar to exaptation processes in earlier investigations (James et al., 2022; Garud et al., 2016a): individuals from different pools of knowledge (network studies, telecom, public health) started a collaboration that persisted over many years.

For the researchers (and in retrospect, the managers), the social network algorithms and successful early-stage testing were seen as a substantial scientific achievement, giving rise to optimism about potential uses. As such, the case also has some elements of more traditional innovation processes tied to a matching of scientific breakthroughs with external needs (Pavitt, 2006; Garud et al., 2013). Still, a main process in our case is tied to extensive later stage work of scaling up and spreading insights and models from small experiments in different locations (O'Reilly and Binns, 2019), not least following the exaptation involving a shift from commercial to public health outcomes.

Our case's timeline has three rather distinct stages. The first one which we have called competence-building, may be seen as more traditional technology push or adaptation where key innovation actors sought potential (commercial) uses, starting from the most immediate ones tied to the company's ongoing market operations. In the second stage, called academic collaboration and reorientation, exaptation emerged through various academic partnerships and new arenas for experimentation with solutions, particularly in South-East Asia. Finally, the last stage of scaling up the innovations for use in regular health responses to pandemics can be tied to minor adjustments and to Covid-19 as a powerful and highly visible challenge that brought various actors together to implement new solutions in a very short timeframe.

As mentioned, the first attempts at scaling up and putting the algorithms and procedures into regular use were tied to economic benefits for the company. Although the researchers found that all these attempts showed positive signs of value creating potentials, scaling up proved difficult. The main challenges were tied to reliance on a few key individuals that changed jobs and a struggle for attention in a company with many different interests. The importance of individuals and their networks supports key claims in the literature on innovation processes (Van de Ven et al., 1990; Pavitt, 2006; Garud et al., 2013). It could be argued that the key researchers in our case played a performative role, "fortune favours the engaged" (Garud et al., 2016a:156). Their narratives about the potentials of the new algorithms and their continuous establishment of new relations supported the later exaptation and made it relatively easy for them to seize the opportunities provided by the Covid-19 outbreak in 2020.

Even in a large multinational company and a setting like public health, both characterised by strong institutional aspects and well-established routines, individuals played a very important role in exaptation and scaling up (cf. O'Connor and Rice, 2001; Garud et al., 2016a). Several champions from the stakeholders were involved, and the processes became vulnerable when these individuals did not last long (see Garud et al., 2016b). This led to what may be also called discontinuity paths (O'Connor and Rice, 2001) with a loss of momentum in diffusion and scaling up that at best retained the small-scale nature of the work. Relatedly, management support is a complicated characteristic of our case. On the one hand, the researchers were given a large amount of freedom to pursue their interests, partnerships, and opportunities. It seems unlikely that the accumulation of knowledge about CDR data in epidemic models would have happened without this part-freedom for the industrial R&D staff, often emphasised in the process literature (Pavitt, 2006; Garud et al., 2013). On the other hand, the lack of clear management support, apart from some enthusiasm surrounding successful pilots and the retrospective pride in the company's role in public health in important markets, is also noticeable. Researchers tied this to reboots and setbacks that might have been avoided or seen weaker impacts on the process.

Almost all the interviewees talked in various ways about chance events and serendipity as important characteristics of the process (cf. Merton and Barber, 2004; Yaqub, 2017). Our case shows that this is not necessarily about luck, but about maintaining and expanding knowledge networks and shaping (or co-creating) opportunities through collaboration with academics and many different potential users (McKelvey et al., 2015; Garud et al., 2016b). Our case fits into two of Yaqub's (2017) serendipity categories. First, a lot of the R&D activities, especially in the first phase, did not have a specific use in mind, which means that it can be tied to "untargeted research solves a later problem". Second, many of the activities were also of the "targeted research solves an unexpected problem" type, for example when viral marketing studies of churning and network diffusion using CDR data suddenly became valuable for understanding epidemics. This may be seen as a special case of exaptation. Even if both these processes were influenced by cross-sector and industry-university networks (e.g. Bogers et al., 2020; McKelvey et al., 2015), Telenor's access to local data and users in many different countries was a key factor, indicating a potential role for large industrial R&D performers in policies aiming to address societal challenges.

Two compelling questions to ask in this regard is at what point a societal problem turns into a "grand" challenge, and whether a shared perception of a grand challenge is needed to achieve the necessary scaling to solve a problem? In our case there were hurdles in implementation of the solutions that were difficult to overcome when the diseases (or solutions) were considered regional, like dengue fever in Pakistan and malaria in Bangladesh (even if the diseases are not confined to these regions). But when the challenge was considered severe and global, like with Covid-19 in early 2020, hurdles were quickly removed, and the developed solution fully implemented in matter of days. This implies that a societal challenge is a moving target, and that problems and their solutions might coexist but not necessarily be aligned in time or that implementation simply is not prioritised by enough actors. Through day-to-day activities rooted in existing resources and ongoing projects, our case thus illustrates that industrial R&D can play a key role in providing solutions to societal challenges. Planning for future

grand challenges is difficult for obvious reasons, hence heterogenous research efforts from different actors – including industrial R&D – may ensure that not all the eggs are placed in the same basket.

6. Conclusion

How Telenor's call detail records (CDR data) became a tool for fighting epidemic diseases and finally was put into regular use for Covid-19 reflects many of the general points of innovation process theories (Van de Ven et al., 1990; O'Connor and Rice, 2001; Pavitt, 2006; Garud et al., 2013, 2016b). The process lasted for decades, saw various unexpected twists and turns, and met many barriers in attempts at what can be termed generalisation: scaling up, diffusion, and regular use beyond smaller-scale experimentation. A central driving force was a small number of enthusiasts from the social network analysis group of the company's R&D department. They continuously redefined the potentials for their initial idea in ways that would benefit the company, but increasingly also benefit society without having a clear link to business opportunities, similar to other innovative responses to the pandemic (James et al., 2022; Yaqub et al., 2022).

We have argued that this could mostly be an example of exaptation whereby a technology finds its use in an area that was not envisaged when the technology was created and in a process with discontinuities rather than continuous evolution (Cattani, 2005; Andriani and Cattani, 2016; Garud et al., 2016a; Andriani and Kaminska, 2021). Many of the happenings in our timeline, especially in the second stage with lots of collaboration with academics and potential users, can be understood as exaptive events tied to exaptive relations and forums (Garud et al., 2016a; James et al., 2022). Our case adds empirically to this growing literature since it is more about a service than a new technology in a strict sense, and because we focus on the scaling up attempts as much as on the idea itself and its progress. More theoretically, our case indicates that exaptation, adaptation and pushing new ideas are processes that are not mutually exclusive but that can happen to some extent simultaneously and at various stages in innovations. Our conceptual and empirical link between process theories and perspectives on societal grand challenges may also prove a starting point for a stronger discussion of process features (beyond organisational and institutional characteristics) in grand challenge theories. The Telenor case suggests that the link between firm's R&D activities and societal challenges can be tied to exaptation and may happen in the middle rather than at the beginning of a process.

More longitudinal work and more focus on social and organisational innovations is still needed, as are studies of other firms represent different sectors, countries, and histories. Key people in Telenor's R&D unit were intimately familiar with the company yet not directly tied to corporate priorities and strategies, which may be a special case. Generalisation events in the Telenor case furthermore point to the need for better understanding of how stakeholders tied to the grand challenge – in our case health policymakers and the specific national health system actors – can become empowered to start a further scaling up of successful innovations from the outside. Current science and innovation support seems to primarily incentivise these activities' direction and knowledge generation rather than training and capacity building. It can be argued that a "grand challenge" perspective means a shift away from focusing on the actions of researchers, research organisations and innovators towards a better understanding the context of use and users of research and innovation.

A practical implication is tied to the finding that the researchers' many ties to operational business units in Telenor opened numerous opportunities for smaller-scale projects and pilots. This can be seen as an experimental (or exaptive) space where smaller-scale actions can be carried out in such a way that they may have transfer value even if the actions themselves are not successful or fail to become implemented or scaled up. Improved horizontal networks (across knowledge pools) could be a way to support innovation processes and to deal with their discontinuities. Another implication comes from the observation that Telenor found the work important because it reflected wider values for the firm, not least in settings with many health and social problems. There may be opportunities from forging explicit links between grand challenge policies and challenges for companies involved in operations in locations where such challenges are very visible. Furthermore, our data indicate that successful scaling up probably requires more formal management or policy support, The use of CDR data for Covid-19 in Norway was ultimately based on previous multi-year collaboration with relevant public health actors and on industrial R&D that was as advanced as the academic frontier research.

Finally, our analysis points at the necessity of a wider perspective both on innovation processes and societal challenges; when it comes to the use of CDR data for fighting pandemics, there are many complex issues about privacy. Even though our case shows that careful work can be done to balance privacy and usefulness needs, this probably constitutes a wicked problem where one comes at the expense of the other. Careful frameworks and policies may be needed to better untangle such situations.

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CRediT authorship contribution statement

Magnus Gulbrandsen: Conceptualisation, Methodology, Data collection, Formal analysis, Writing – first draft and revision, Project administration, Funding acquisition.

Erlend Simensen: Conceptualisation, Methodology, Data collection, Formal analysis, Writing – first draft and revision, Project administration.

Data availability

The data that has been used is confidential.

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Magnus Gulbrandsen is professor at TIK Centre for Technology, Innovation and Culture at the University of Oslo. His research addresses broad themes within science and innovation policy such as quality, impact and interaction between researchers and users, commercialization of research and internationalization. A main interest for him is how and under which conditions research-based knowledge is taken up and used in society. This is also the topic of the Oslo Institute for Research on the Impact of Science (OSIRIS), an 8-year project that Gulbrandsen has led since its startup in 2016. He has published in leading scientific journals and worked with industry and policymakers.

Erlend Osland Simensen is a researcher in the OSIRIS project, currently affiliated with NORSUS. His work concentrates on industrial case studies, sector systemic perspectives on innovation and on longitudinal analyses of research and innovation data. He uses both quantitative and qualitative research methods including social network analysis, case study methodology and regression models.