Managing Complexity in Large Bimodal IT Projects

1. Relevance relative to the call for proposals

The objective of Frinatek is to promote "scientific quality in the international research front" and "bold and innovative research". This project seeks to develop the software engineering and project management research disciplines by providing revelatory studies in an area critical for society. The project will be carried out by the SINTEF research group which is the top-ranked institution in the world on agile methods. The group will collaborate with a leading project management research group at the Norwegian University of Science and Technology with large impact on the Norwegian project management community through *Project Norway.* The position as one of the countries with most mature use of agile methods, and one of the main international research environments with focus on agile methods, an established project uncertainty research environment, and collaboration with leading international partners provides a unique possibility for ground-breaking studies in this project.

2. The research project

Software is critical to our society, yet development of software remains a challenge as documented in a survey of IT projects from the University of Oxford (Flyvbjerg and Budzier 2011), which finds an average overrun on costs of 27%. The British report on "Challenges of Complex IT Projects" describes IT projects as particularly demanding as there is a perception of a lack of constraints on IT solutions, the systems are difficult to visualize, it can be difficult to elucidate clear requirements from people, and the complexity of large scale IT systems is "insufficiently well understood".[1] Large projects are particularly demanding. In a recent interview in *IEEE Software* with Budzier from the University of Oxford on "why large IT projects fail", he emphasizes that the 1ong duration and transformative potential for the user organization are central characteristics.[2]

Large IT projects therefore shift the role of the IT function. Bimodal IT suggests managing IT projects according to whether they are in well understood and predictable areas - *Mode 1,* or exploratory or uncertain areas - *Mode 2* (Haffke et al. 2017). Gartner Group argues that companies need to master both areas, and Mode 2 because current organizations demand ”...an IT function that is at the forefront of exploring digital options that can create competitive advantage for the firm, which may mean actively searching, assessing and experimenting with new digital possibilities" (Haffke et al. 2017). Development in *Mode 2* increases complexity as the nature of the solution is uncertain when planning the work, which makes Gartner recommend agile methods.

This advice is based on the success of agile methods in small Mode 2 projects. The first generation of agile development methods sought to handle the complexity of software development through a small set of practices: Development in small self-managed teams, frequent integration of all system modules, and frequent feedback from customers and end-users. These methods have radically changed the way software is developed (Dingsøyr et al. 2012), receiving widespread interest in particular in the software engineering field, but also in the project management community (Hobbs and Petit 2017). Given the success of agile methods in small projects, they are now increasingly used also in large-scale IT projects.

As an empirical example of a large-scale Mode 2 project, consider the four-year Perform Programme for the Norwegian Public Service Pension Fund (Dingsøyr et al. 2018b). This is the largest completed project with extensive use of agile principles so far in Norway. Perform developed a system to administer pensions for 960 000 citizens. Development was carried out by up to twelve teams developing 2.500 user stories, using about 800 000 person hours. The programme is considered the largest agile success programme in Norway so far. This IT project shares characteristics with megaprojects in the project management literature with respect to number of actors, complexity and risk (Söderlund et al. 2017).

[1]Royal Academy of Engineering, "The Challenges of Complex IT Programmes", report from working group from the *Royal Academy of Engineering and the British Computer Society*, 2004. ISBN 1-903496-15-2.
[2]Robert Blumen: "Jürgen Laartz and Alexander Budzier on Why Large IT Programmes Fail", *IEEE Software,* july/august 2016.

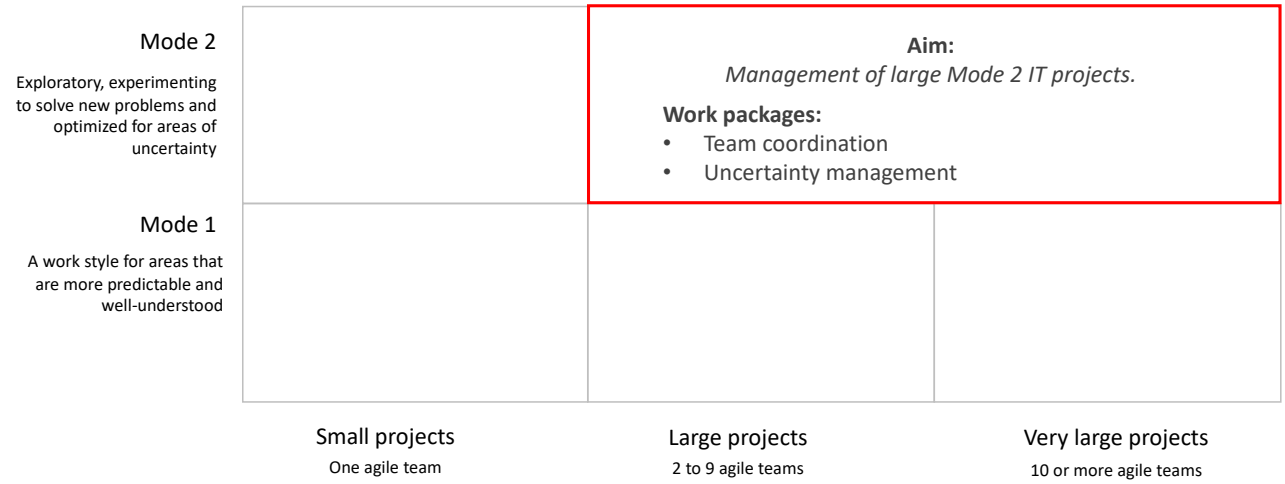

Figure 1: *Type of area and project size, with large Mode 2 IT projects in top right corner.*

As agile methods are used on large-scale projects, new challenges arise. An international survey on agile adoption[3] indicates that agile methods have primarily been successful in small projects (93% success rate, while large projects have a 62% success rate). Many have been critical to applying agile methods in large scale because of lack of focus on software architecture, and because the informal communication in agile methods is not believed to be efficient given the number of people, number of teams and complexity of the product developed. Self-managing teams are central in agile methods, but increased autonomy for teams could increase difficulties in aligning the work of a number of teams. A second generation of agile development methods is emerging which provides practitioner advice, such as the Project Management Institute´s *Agile Practice Guide* (2017), methods such as *Scaled Agile Framework*[4], and *Large-Scale Scrum*[5], in books such as Leffingwell´s *Scaling Software Agility* (2007). But there is precious little advice based on scientific studies.

This project seeks to develop new theory to enable better management of large IT projects. We target a particularly challenging domain, namely projects or programs operating in the Mode 2 area, which have an increased complexity due to both uncertainties concerning the work to be done, and to size with respect to number of participants and duration. An indicator of size is the number of teams working on software development. The very-large projects represent extreme cases, and theory relevant for this domain is likely to extend our understanding also of smaller projects. Our focus in this project will be large and very-large Mode 2 projects (see Figure 1). We seek to provide contributions both to the software engineering and project management disciplines.

But why focus on large projects when general advice in the project management and software development communities is to avoid large programmes (Flyvbjerg et al. 2003) and "big software" (Andriole 2017)? Even though the advice is to keep programmes small, it is often impossible to provide value from projects without large scale efforts (as for projects in Table 1). Today, large-scale digital transformations are critical for large corporations and governments. In order to succeed with such transformations, we need information systems development methods that handle the increasing complexity due to project size and degree of transformation of a customer organization. Due to the criticality of these projects, the methods should to a larger degree be based on research. This project will target the following two key challenges for management of large Mode 2 IT projects:

Team coordination: as the number of dependencies increase and methods to handle dependencies in small scale have shown to be insufficient in large-scale development with many development teams.

Uncertainty management: as Mode 2 projects focus on areas of uncertainty and need approaches which can blend traditional project management methods with new approaches to handle uncertainty in agile methods.

By focusing on these two challenges, our project will be interdisciplinary in nature, bridging the software engineering and project management disciplines. The ambition is to provide revelatory studies of high relevance to IT practitioners and managers of knowledge-based projects in general.

[3]Scott Ambler: Agile Adoption Rate Survey 2008, http://www.ambysoft.com/surveys/agileFebruary2008.html
[4]http://www.scaledagileframework.com/
[5]http://less.works/

Challenge 1: Team coordination in large Mode 2 IT projects

Coordination can be understood as “management of interdependencies between activities” (Malone and Crowston 1994) and coordination mechanisms are the organizational arrangements, which allow individuals to realize a collective performance (Okhuysen and Bechky 2009). Interdependencies include sharing of resources, synchronization of activities, and prerequisite activities. Basic mechanisms for coordination in management science (Mintzberg 1989) include: direct supervision, mutual adjustment, and standardization of work, outputs, skills and norms.

Agile methods de-emphasize traditional coordination mechanisms such as forward planning and extensive documentation (Strode et al. 2012) and mainly promote informal coordination (Xu 2009). Agile development methods "embrace" change by moving decision authority to the team level, making rough long-term plans and detailed short-term plans. In their article entitled "why Scrum works", Pries-Heje and Pries-Heje (2011) states that Scrum "requires very little time trying to foresee and negotiate the work flow and coordination mechanisms prior to actually conducting the work". They emphasize four artifacts that they believe are especially useful for coordination: The product backlog, the sprint backlog, the scrum board and the daily meetings.

In large-scale projects, however, a study on coordination breakdowns state that "*the success of software development projects depends on carefully coordinating the effort of many individuals across the multiple stages of the development process"* (Cataldo and Herbsleb 2013). Prior studies on coordination of large-scale agile development have shown that arenas such as Scrum of Scrums are ineffective (Paasivaara et al. 2012), that lack of coordination can be traced back to misaligned planning on inter-team level (Bick et al. 2017), and that coordination happens through a number of arenas and change over time (Dingsøyr et al. 2018b, Dingsøyr et al. 2018c). A survey on coordination in large-scale software teams found respondents to hope for more effective and efficient communication and an emphasis on the importance of good personal relationships (Begel et al. 2009).

We need to develop a better understanding of coordination in Mode 2 IT projects, because:

- There is currently little advice on inter-team coordination available to practitioners in new frameworks for large-scale agile development such as *SAFe* and *LeSS*.
- Coordinating knowledge work is an important topic in project management, and software development is an extreme case of knowledge work with rapid changes in technology.
- Coordination is crucial for the success of complex large Mode 2 IT projects, and more effective ways of coordination will give large societal benefits.

One could argue that coordination is an old topic and that we know "enough" about the enabling mechanisms. However, the emergence of agile methods puts emphasis on new coordination mechanisms, and we have argued in a workshop paper that we need to rethink coordination on large-scale software development (Dingsøyr et al. 2018a). In particular, we need to develop our understanding of how coordination needs and practices change over time. We will therefore investigate the following research question:

RQ1: How can coordination in Mode 2 IT projects be understood over time by drawing on coordination theories?

Challenge 2: Uncertainty management in large Mode 2 IT projects

Risk is predominantly perceived with a negative connotation, but risk is defined by the *Project Management Institute* as "an uncertain event or condition, that, if it occurs has a positive or negative effect on one or more project objectives" (Petit and Hobbs 2010). In the following we use the term *uncertainty management* as a broader term which draws attention to the need to understand variability in future activities (Duncan 1972).

In the 90ies, there was a concern within the software engineering community on the ability of software projects to deliver on time, cost and quality. Some used the word “software crisis” (Kraut and Streeter 1995). A study of risk factors (Keil et al. 1998) shows that key concerns for software projects were related to the customer. Since then, the response from the industry was to focus on flexibility by applying agile development methods which seek to reduce risks by frequent delivery, integration and dialogue with clients and users. This is a very different strategy than what is prescribed in the project management field in general, where most approaches focus on controlling uncertainty. Agile methods, however, seeks to cope with uncertainty through flexible management of projects (Dönmez and Grote 2018, Olsson 2006).

However, these methods were originally aimed at small, co-located teams making software that is not life-critical (Conforto et al. 2014). Key characteristics of agile development is that development takes place in self-managed teams, that the main design decisions (the architecture of the system to be developed) is to emerge

rather than to be the result of up-front design, and that users are involved in the development process through taking part in demonstrations such as in the Scrum development process, or through the practice of "customer on site" in extreme programming (Beck and Andres 2004). These characteristics mean that uncertainty management to a large extent could be integrated in the daily work of the agile teams. Project uncertainty management has traditionally focused on efficiency, typically related to time, cost and scope. However, agile methods integrate work on both efficiency and effectiveness to a larger extent than other large projects. This means that established uncertainty management techniques are not directly transferable to *Mode 2* IT projects.

We need to develop a better understanding of uncertainty management in Mode 2 IT projects, because:

- While agile methods include a number of implicit measures to handle risks and opportunities in small-scale agile development (Odzaly and Des Greer 2014) it is an open question how this is handled in large scale.
- *Mode 2* IT projects are extreme cases of uncertainty in technology and customer organisation, and existing uncertainty management need to be adjusted to an agile environment.
- Managing uncertainty is crucial for the success of complex large Mode 2 IT projects.

But uncertainty management has been researched since the 90ies, why is there a need to further investigate this topic now? Agile approaches lead to new ways of managing uncertainty which have so far received little attention, in particular we have not been able to identify previous studies on management of uncertainty in large projects using agile methods. Agile software development need to stay agile even when it is moved to large scale projects, but there is also a need to have an overview of potential risks and to be able to utilise emerging opportunities. To do so, uncertainty management suitable for Mode 2 IT projects is needed. This project will investigate the following research question:

RQ2: How are methods from traditional and agile development applied to manage uncertainty in Mode 2 IT projects over time?

Answering the research questions stated will provide thorough insight into a field with few existing studies. The combination of a mature agile environment in Norway[6], a leading research environment on agile methods and an established project uncertainty research environment enables studies that will have high impact in academia and industry. We will provide rich descriptions of projects that are unavailable to others and we can utilise a large amount of experiences from uncertainty management in a wide range of large projects. This project will contribute to improving software engineering research with respect to research rigour and the project management discipline with respect to relevance to the software development industry.

Research Method: One of the main advocates of case study research, Flyvbjerg, argues that "a discipline without exemplars is an ineffective one" (Flyvbjerg 2006). There are few existing studies of complex large IT projects with emphasis on information systems development. We will investigate the research questions in real-world projects, using an embedded case study design (Runeson and Höst 2009). We will use the research method extended case study (Burawoy 1998), which has been in use in other research fields, but is relatively unknown in software engineering and project management. The extended case study method puts emphasis on longitudinal observation and making a theoretical contribution. Case studies are particularly important to understand emerging phenomena such as agile development methods.

We will choose two large Mode 2 IT projects that satisfy our criteria for being large-scale (see page 2), and will be *extreme* cases, in size and complexity, and that follow an agile contract model such as the PS-2000 SOL.[7] Case studies will be performed in two phases as shown in the project plan, with initial work on four pilot cases, and then selection of two for longitudinal studies. For the longitudinal studies, one case will be selected according to criteria for contributing to research on each work package topic, but we will also conduct data collection on the other topic (see section 3). Further, we require that the projects must take more than two years in order to do longitudinal studies, and we prefer projects that are co-located in order to avoid additional challenges related to geographical distribution or sociocultural distance in global projects.

Two potential cases are described in Table 1. The "Project 2" of the Norwegian Labour and Welfare Administration offers a unique opportunity to study one of the largest IT project in Norway so far, which will develop solutions for 21.000 employees, which provides money transfers and services to 2.8 million Norwegian citizens. This project will be followed by "Project 3" which is another potential case from 2019-2020, and other potential cases are digital transformation projects for main companies and public institutions

[6]Norway has the highest number of «certified Scrum Masters» per capita, and large discussion groups focusing on agile development like XP meetup in Oslo with over 1800 participants and XP/Agile Meetup in Trondheim with over 500 members.
[7]https://ps2000.wordpress.com/category/ps2000-sol/

in Norway such as Kongsberg Group, Norwegian Public Roads Administration, the Norwegian Tax Administration, Sopra Steria, Statoil, Telenor or members of *Project Norway* (see section 3).

Table 1: *Initial potential large-scale development projects for study.*

Project	Duration	Description
Project 2	2016-2019	The Norwegian Labour and Welfare Administration will modernize their IT infrastructure for EUR 140 million in the "Project 2". This is a partial continuation of the "modernizing" project, which involved 17 development teams working in parallel using agile development methods, but was stopped in 2013.
Project 3	2019-2020	Final continuation of the "modernizing" project, expected to be a larger project than "Project 2".

Data sources will be participant observation, interviews, focus groups as well as relevant archival data and metrics about the development process and product. Procedures of data collection will be defined in our case study protocol. We will not collect sensitive personal data, but recording interviews and observing participants will require informed consent and approval from the Norwegian Data Protection Official for Research.

The data will be analysed using several strategies as outlined by Langley (1999). Relevant strategies include the narrative, alternate template, grounded theory, visual mapping and temporal bracketing theory. We will follow a flexible research design, where we adjust theory use after we obtain a deep insight of the cases. High validity of our findings will be achieved through data source triangulation, methodological triangulation, having the data collection protocols reviewed by peer researchers, and by having data material and conclusions of studies presented to informants for member checking. Further, we will use alternative theories to explain findings (theory triangulation).

Why focus on case studies and not use other research methods? A common critique of case studies is that one cannot generalize findings, but as Flyvbjerg (2006) argues, generalization can be done through theory. In addition, case studies will provide critical insight for both industry and academia as examples with detailed descriptions of context. The first ethnographically inspired studies of XP practices by the Open University in the UK (Sharp and Robinson 2004) were central in overcoming scepticism to agile methods in industry and in academia. Readers of case studies can learn from previous cases through analysis of what is relevant for their own situation. But in addition to conducting case studies, this project will also nurture quantitative studies through engaging the international research community in submitting workshop contributions and articles to a journal special issue.

3. Project plan, project management, organisation and cooperation

We describe main objectives, work organisation, participating research environments and national as well as international collaboration:

Objectives: The primary objective is to develop the software engineering and project management research disciplines by making both theoretical and methodological contributions in an area of vital importance for the society: *Management of large Mode 2 IT projects.*

Secondary objectives:

1. *Provide revelatory empirical studies of how teams are coordinated in complex large IT projects, and explain the findings using relevant theories.*
2. *Provide revelatory empirical studies of how uncertainties are managed in complex large IT projects, and explain the findings using relevant theories.*
3. *Collaborate actively with leading international software engineering and project management environments.*
4. *Disseminate knowledge to the wider research community by publishing in top international journals and conferences.*
5. *Organize a workshop at a major international conference on managing complexity in large bimodal IT projects.*
6. *Publish a special issue on managing complexity in large bimodal IT projects in a top international journal.*

The project work is divided into the following four work packages:

WP1: Project management
WP leader: Dr. Torgeir Dingsøyr

Objective: To carry out the management, coordination and reporting activities in the project necessary to:

- Ensure effective implementation of project activities in line with the guidelines from the Research Council and the Project Contract.
- Handle deviations from plans, exploit opportunities, and take proper actions to reach the main objectives.

Description of work

- Constitute and run the project management.
- Manage the administrative tasks of the project, including communication and progress reporting to the Research Council.
- Coordinate the research activities in the project.

Deliverables

- Project plan, dissemination plan, web site and publication strategy.
- Progress status reports every six months and quarterly blog postings on progress.
- Application to the European Research Council *Advanced Grant* on coordination and uncertainty management.

WP2: Team coordination
WP leader: Dr. Torgeir Dingsøyr

Objective: To synthesize prior knowledge on and extend this knowledge through longitudinal embedded case studies. Develop theory to explain the fundamental mechanisms that enable team coordination in complex large bimodal IT projects.

Description of work

- Synthesize findings from studies identified in the literature.
- Conduct case studies in two large-scale development projects, lead the study of one case.
- Active international collaboration through conducting studies, co-authoring articles.
- Lead editing of a journal special issue.

Deliverables

- 2 journal articles from case studies.
- 3 conference papers: covering aspects not reported in the above articles.
- 1 popular scientific article in magazine.
- 1 journal special issue (and introduction article).

WP3: Uncertainty management
WP leader: Dr. Nils Brede Moe

Objective: To synthesize prior knowledge on and extend this knowledge through longitudinal embedded case studies. Develop theory to explain how uncertainty management influence the development process complex large bimodal IT projects.

Description of work

- Synthesize findings from studies identified in the literature.
- Conduct case studies in three large-scale development projects, lead the study of one case.
- Active international collaboration through conducting studies, co-authoring articles and co-organizing workshops.

Deliverables

- 2 journal articles from case studies.
- 3 conference papers: covering aspects not reported in the above articles.
- 1 popular scientific article in magazine.

WP4: Research education
WP leader: Prof. Bjørn Andersen

Objective: To educate researchers and practitioners on large bimodal IT projects.

Description of work

- Recruit a highly qualified postdoc candidate, giving priority to recruiting women.
- Involve master's degree students in the research topics in the project.
- Incorporate research findings from the project in courses at the Norwegian University of Science and Technology.

Deliverables

- 2 teaching cases published in international journals such as the *Project Management Journal.*
- Education material at master's and PhD levels.
- 5 master's degree theses.

Milestones: Main milestones in the project will be the following (aggregated numbers for publications):

Month 3:	Agreements with two pilot cases, application to Norwegian Data Protection Official for Research approved. Initial case study protocol developed.
Month 6:	Two pilot case studies completed, selection of one case for longitudinal studies with primary focus on *team coordination* and secondary focus on *uncertainty management.* Case study protocol complete and reviewed by international partners. Suggestion for workshop at international conference submitted.
Month 15:	Agreements with two new pilot cases. 1 paper published at international conference.
Month 18:	Selection of case for longitudinal study with primary focus on *uncertainty management* and secondary focus on *team coordination.* 3 papers published at international conferences. Workshop conducted at international conference.
Month 30:	First embedded case studies completed. 2 journal articles published, 5 papers published at international conferences.
Month 42:	Second case study completed. 4 journal articles published, 6 papers published at international conferences.
Month 48:	Special issue published in major international journal. All publications delivered from the project. Knowledge developed reported to relevant governmental institutions and industry associations.

The main risk in this project is the quality of the cases selected for study. We show potential cases in Table 1, where we already have established relations. Further, we have relations to many of the main software development environments in Norway through other projects (described below), which can then replace the cases if a case project should be terminated or show not to provide novel contributions. To assess quality of cases and build relations, we plan to conduct 4 pilot case studies where we study all the themes of the project, and then select 2 cases for extensive longitudinal studies.

The project will be led by the process improvement group at SINTEF Digital, in collaboration with researchers in *Project Norway* at the Norwegian University of Science and Technology (NTNU). We briefly describe each environment and their involvement:

The software process improvement group, SINTEF: The group has in particular focused on agile methods and software process improvement and has been ranked as the most active research environment in the world on agile development methods (Chuang et al. 2014). Chief scientist Dr. Torgeir Dingsøyr will be project manager (see attached CV for project management experience), senior scientists Dr. Nils Brede Moe will be responsible for work package 3, and Dr. Knut Rolland involved in research tasks in work packages 2 and 3. The project manager will be responsible for administrative matters in the project, and will report to research director Dr. Maria Bartnes.

Department of Mechanical and Industrial Engineering, Norwegian University of Science and Technology hosts *Project Norway* as of the main environments on project management at the university. Prof. Bjørn Andersen is an internationally recognized expert in project management and has been researching project management issues since 1995; he will manage work package 4. Prof. Nils Olsson has extensive experience as a consultant, research scientist, and manager. The consulting experience include risk manager assignments in IT projects and mega projects for Ernst & Young and DNV GL. Prof. Olsson will be involved in research tasks in work package 3.

SINTEF is currently running a related project as main contractor and in collaboration with NTNU: The *Agile 2.0* competence-building project (Project manager: Chief scientist Dr. Torgeir Dingsøyr, NOK 25 million, 2014-2020) funded by the Research Council of Norway and companies Kantega, Kongsberg Defence&Aerospace, Sopra Steria and Sticos. The project conducts action research and company-spanning studies on distributed, large-scale and safety-critical agile development

National cooperation: In addition to the collaboration between SINTEF and NTNU, these research environments have extensive collaboration with the University of Oslo (Prof. Dag Sjøberg) and the University of Bergen (Prof. Bjørnar Tessem). This collaboration has been particularly fruitful in investigating the same topics by triangulating on method such as quantitative methods in studies with the University of Oslo or having presence in several cities in order to follow a project from several sites as with an ongoing collaboration with the University of Bergen. Prof. Bjørn Andersen is the manager of *Project Norway* which is a research-based collaboration hosted at the Norwegian University of Science and Technology. The purpose of the center is to

develop and distribute new knowledge within project-based activity through research, cooperation, and knowledge sharing between public and private sector industry and academic institutions. This research proposal is aligned with interests of participating organizations. Project Norway has previously initiated research on agility in other sectors than software and on uncertainty management in the civil engineering sector. Uncertainty management has for a long time been one of the key focus areas of project management research at NTNU.

International cooperation: This project will increase existing ties with international partners. These partners represent leading institutions in this field from Ireland, USA, Canada and Sweden. We are working on a journal extension of an article to the *International Conference on Information Systems* on large-scale agile development with Prof. Fitzgerald and Dr. Stool at Lero (Irish Software Research Centre), this project will allow us to continue this collaboration. In 2012, we co-edited a special issue in the *Journal of Systems and Software* with Prof. Sridhar Nerur at the University of Texas. His focus on theory in explaining agile methods will be of immense value in this project. Prof. Yvan Petit is part of the Project Management Research Chair and a professor at ESG UQAM in Montreal, Canada, He is currently editing a special issue in the *Project Management Journal* on agile approaches (to appear in 2018) and has recently published on the topic of Scaling Agile. He was on a research stay at SINTEF in 2017 and will be involved in co-authoring articles in this project. Another ongoing collaboration is with one of the leading software engineering environments in the world at Blekinge Institute of Technology in Sweden. Prof. Darja Šmite is leading a project on *Governance in large-scale distributed agile software development* (2017-2019) with large companies such as Ericsson and Telenor as partners. Dr. Nils Brede Moe and Prof. Darja Šmite have previously written articles on large development projects at Ericsson. We will both continue writing articles and organizing workshops as collaboration between the projects. Further, partners will assist in designing and conducting studies, organizing open project seminars and editing a journal special issue. They will regularly visit SINTEF as guest researchers, and the Norwegian project participants will visit their institutions. The partners will take the following roles in collaboration:

Table 2: *Names, institutions and roles for collaborating partners in the project.*

Name	Institution	Role
Prof. Brian Fitzgerald	University of Limerick, Ireland	Empirical studies of large-scale agile development, in particular method tailoring and coordination.
Prof. Sridhar Nerur	University of Texas, USA	Theory development, team coordination and sociotechnical systems.
Prof. Yvan Petit	Université du Québec à Montréal, Canada	Uncertainty management, agile approaches in project management.
Prof. Darja Šmite	Blekinge Institute of Technology, Sweden	Empirical studies of large-scale global software development projects, in particular governance of large IT projects.

4. Key perspectives and compliance with strategic documents

Relevance and benefit to society: How to manage large Mode 2 IT projects is a vital question for companies developing software. In this project we will increase the understanding of such complex projects by providing in-depth longitudinal studies of two key themes in managing such projects: large-project team coordination and uncertainty management.

Answering the research questions stated previously will provide thorough insight into a field with few existing studies. The combination of a mature agile environment in Norway and a leading research environment on both agile methods and uncertainty management enables studies that will have high impact in academia and industry. We will provide rich descriptions of practices that are unavailable to others.

Norway needs leading international research environments to secure a highly competent and productive software sector. SINTEF is an applied research institute with a mission to deliver relevant research results to the Norwegian software sector. The companies in this sector emphasize that collaboration with the leading-edge expertise in the project is essential for their business, as R. Glass expressed: “Here’s a message from software practitioners to software researchers: We need your help. We need some better advice on how and when to use methodologies” (Glass 2004). This project will develop knowledge that is critical for the success of projects that are of vital importance to the private business and the society at large.

In addition to the benefits for the participating cases and the software sector, the knowledge developed in this project will be important for project management in other disciplines such as engineering and construction, which are taking up similar work practices as the software sector for example using concurrent engineering and lean construction.

Other benefits are: First, improved software projects will give end-users of software systems earlier solutions with higher quality. For example, the current reform in the Norwegian Labour and Welfare Administration is highly dependent on software. Second, focus on agile development principles will affect the quality of working life for developers; the principles extend the Scandinavian organization of work. Third, the project will strengthen focus on empirical research in the fields of software engineering and project management, which will have a large impact in advancing the fields. The position as one of the countries with most mature use of agile methods, and one of the main international research environments provides a unique possibility for ground-breaking studies in Norway, to make management of large Mode 2 IT projects more knowledge-based.

Environmental impact: The direct environmental impact of the project is due to travel. We will exploit virtual collaboration technology as much as possible, which we expect will reduce the impacts of travel by 20%.

Ethical perspectives: All empirical studies in the project will be conducted according to the guidelines of the National Committee for Research Ethics in Science and Technology.[8] The data collection will be done in accordance with requirements from the Norwegian privacy ombudsman for research.[9]

Gender balance and recruitment of women: In accordance with the actions defined by the Research Council for promoting gender equality,[10] we will treat the issue of gender mainstreaming by giving equal consideration to the life patterns, needs, and interests of both women and men. There is a consistent lack of female engineers and scientists in Norway. The project members are aware of the ways to comply with gender related differences. NTNU has long tradition on supporting females' engagement with technology, in particular the program Women in Technology (http://www.ntnu.no/jenter) will be used to further disseminate and ensure a balanced gender perspective.

5. Dissemination and communication of results

With this project, we seek to develop an internationally recognized environment in the borderline between the software engineering and project management disciplines. To reach this goal, we have ambitious plans for scientific publication:

Table 3: *Publication plan.*

Type of publication	2020	2021	2022	2023	2024	Total
Articles in leading international peer-reviewed journals			2	2	2	6
Papers at international peer-reviewed academic conferences	1	2	2	1		6
Popular scientific articles in magazines			1	1		2
International research workshop		1				1
Special issue in leading international peer-reviewed journal				1		1

For journal articles, we will target top software engineering and project management journals which offer open access publication such as *IEEE Transactions on software engineering, Information and Software Technology* and the *Journal of Systems and Software, International Journal of Project Management* and *Project Management Journal*. For academic conferences, we will both target the *International Conference on Software Engineering* and the *IRNOP project management conference,* as well as conferences that focus particularly on agile software development, such as the *International Conference on Agile Development ("XP").* As for magazines, we will primarily aim at *IEEE Software* and *IEEE IT Professional*, which have broad readerships in the software industry.

[8] The National Committee for Research Ethics in Science and Technology, see http://www.etikkom.no/retningslinjer
[9] See http://www.nsd.uib.no/personvern/om/english.html
[10] See Handlingsplan for likestilling i FoU-sektoren (Action plan for gender equality in research and education).

References

Andriole, S. J., "The death of big software," *Communications of the ACM,* vol. 60, pp. 29-32, 2017.

Beck, K. and Andres, C., *Extreme Programming Explained: Embrace Chage (2nd ed)*: Addison-Wesley, 2004.

Begel, A., Nagappan, N., Poile, C., and Layman, L., "Coordination in large-scale software teams," in *Proceedings of the 2009 ICSE Workshop on Cooperative and Human Aspects on Software Engineering*, 2009, pp. 1-7.

Bick, S., Spohrer, K., Hoda, R., Scheerer, A., and Heinzl, A., "Coordination Challenges in Large-Scale Software Development: A Case Study of Planning Misalignment in Hybrid Settings," *IEEE Transactions on Software Engineering,* 2017.

Burawoy, M., "The Extended Case Method," *Sociological Theory,* vol. 16, pp. 4-33, 1998.

Cataldo, M. and Herbsleb, J. D., "Coordination Breakdowns and Their Impact on Development Productivity and Software Failures," *IEEE Transactions on Software Engineering,* vol. 39, pp. 343-360, 2013.

Chuang, S.-W., Luor, T., and Lu, H.-P., "Assessment of institutions, scholars, and contributions on agile software development (2001–2012)," *Journal of Systems and Software,* vol. 93, pp. 84-101, 2014.

Conforto, E. C., Salum, F., Amaral, D. C., da Silva, S. L., and de Almeida, L. F. M., "Can agile project management be adopted by industries other than software development?," *Project Management Journal,* vol. 45, pp. 21-34, 2014.

Dingsøyr, T., Bjørnson, F. O., Moe, N. B., Rolland, K., and Seim, E. A., "Rethinking Coordination in Large-Scale Software Development," presented at the Workshop on Cooperative and Human aspects in Software Engineering (CHASE), *International Conference on Software Engineering*, Gothenburg, Sweden, 2018a.

Dingsøyr, T., Moe, N. B., Fægri, T. E., and Seim, E. A., "Exploring Software Development at the Very Large-Scale: A Revelatory Case Study and Research Agenda for Agile Method Adaptation," *Empirical Software Engineering,* vol. 23, pp. 490-520, 2018b.

Dingsøyr, T., Moe, N. B., and Seim, E. A., "Coordinating Knowledge Work in Multi-Team Programs: Findings from a Large-Scale Agile Development Program," *To appear in Project Management Journal. arXiv preprint arXiv:1801.08764,* 2018c.

Dingsøyr, T., Nerur, S., Balijepally, V., and Moe, N. B., "A Decade of Agile Methodologies: Towards Explaining Agile Software Development," *Journal of Systems and Software,* vol. 85, pp. 1213-1221, 2012.

Dönmez, D. and Grote, G., "Two sides of the same coin – how agile software development teams approach uncertainty as threats and opportunities," *Information and Software Technology,* vol. 93, pp. 94-111, 2018/01/01/ 2018.

Duncan, R. B., "Characteristics of organizational environments and perceived environmental uncertainty," *Administrative science quarterly,* pp. 313-327, 1972.

Flyvbjerg, B., "Five Misunderstandings about Case Study Research," *Qualitative Inquiry,* vol. 12, pp. 219-245, 2006.

Flyvbjerg, B., Bruzelius, N., and Rothengatter, W., *Megaprojects and risk: An anatomy of ambition*: Cambridge University Press, 2003.

Flyvbjerg, B. and Budzier, A., "Why Your IT Project May Be Riskier Than You Think," *Harvard Business Review,* vol. 89, pp. 22-25, 2011.

Glass, R. L., "Matching Methodology to Problem Domain," *Communications of the ACM,,* vol. 47, pp. 19-21, 2004.

Haffke, I., Kalgovas, B., and Benlian, A., "Options for Transforming the IT Function Using Bimodal IT," *MIS Quarterly Executive,* vol. 16, pp. 101-120, 2017.

Hobbs, B. and Petit, Y., "Agile Methods on Large Projects in Large Organizations," *Project Management Journal,* vol. 48, pp. 3-19, 2017.

Keil, M., Cule, P. E., Lyytinen, K., and Schmidt, R. C., "A framework for identifying software project risks," *Communications of the ACM,* vol. 41, pp. 76-83, 1998.

Kraut, R. E. and Streeter, L. A., "Coordination in software development," *Communications of the ACM,* vol. 38, pp. 69-81, 1995.

Langley, A., "Strategies for Theorizing from Process Data," *The Academy of Management Review,* vol. 24, pp. 691-710, 1999.

Leffingwell, D., *Scaling software agility: best practices for large enterprises.*: Pearson Education, 2007.

Mintzberg, H., *Mintzberg on management: Inside our strange world of organizations*: Simon and Schuster, 1989.

Odzaly, E. E. and Des Greer, D. S., "Lightweight Risk Management in Agile Projects," presented at the 26th Software Engineering Knowledge Engineering Conference, Vancouver, Canada, 2014.

Okhuysen, G. A. and Bechky, B. A., "Coordination in Organizations: An Integrative Perspective," *Academy of Management Annals,* vol. 3, pp. 463-502, 2009.

Olsson, N., "Management of flexibility in projects," *International Journal of Project Management,* vol. 24, pp. 66-74, 2006.

Paasivaara, M., Lassenius, C., and Heikkila, V. T., "Inter-team Coordination in Large-Scale Globally Distributed Scrum: Do Scrum-of-Scrums Really Work?," in *Proceedings of the ACM-IEEE International Symposium on Empirical Software Engineering and Measurement*, ed New York: IEEE, 2012, pp. 235-238.

Petit, Y. and Hobbs, B., "Project portfolios in dynamic environments: sources of uncertainty and sensing mechanisms," *Project Management Journal,* vol. 41, pp. 46-58, 2010.

Pries-Heje, L. and Pries-Heje, J., "Why Scrum works: A case study from an agile distributed project in Denmark and India," in *Agile Conference (AGILE), 2011*, ed: IEEE, 2011, pp. 20-28.

Project Management Institute, *Agile Practice Guide*, 2017.

Runeson, P. and Höst, M., "Guidelines for conducting and reporting case study research in software engineering," *Empirical Software Engineering,* vol. 14, pp. 131-164, 2009.

Sharp, H. and Robinson, H., "An ethnographic study of XP practice," *Empirical Software Engineering,* vol. 9, pp. 353-375, 2004.

Söderlund, J., Sankaran, S., and Biesenthal, C., "The Past and Present of Megaprojects," *Project Management Journal,* vol. 48, pp. 5-16, 2017.

Strode, D. E., Huff, S. L., Hope, B. G., and Link, S., "Coordination in co-located agile software development projects," *Journal of Systems and Software,* vol. 85, pp. 1222-1238, 2012.

Xu, P., "Coordination in large agile projects," *The Review of Business Information Systems,* vol. 13, p. 29, 2009.