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increasing intervention capacities for enhancing project management reflections on complexity

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RESEARCH ARTICLE

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Responsible innovation during front-end development: increasing intervention capacities for enhancing project management reflections on complexity

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ABSTRACT

Responsible innovation requires, among other things, that innovators reflect on the broader socio-ethical and socio-economic context of their work. This may be done by reflecting on innovation project complexity. However, tools and methods enabling relevant reflection are not abundant. In this explorative study, we investigated the effect of explicitly stimulating reflection about complexity during innovation project front-end development, using Midstream Modulation (MM) in combination with a complexity framework that distinguishes technical, organizational and external (TOE) aspects. Three project leaders in engineering and construction within the Dutch process industry interacted regularly with a critical outsider, following MM protocols, while also discussing relevant TOE aspects. Our method proves useful in supporting deliberations, and helps to broaden and deepen considerations regarding TOE aspects. The findings show the possibility and utility of enhancing reflection during early phases of innovation project management, in a way that advances both ongoing projects and responsible innovation objectives.

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Project management; responsible innovation; strategic communication; decision support

Introduction

Context

Following Stilgoe, Owen, and Macnaghten (2013), responsible (research and) innovation requires reflexivity, anticipation, inclusion and responsiveness regarding the socio-ethical and socio-economic context of innovation work, particularly by those involved in such work. To help innovators consider such contexts, opening up communication and interaction with others is crucial. Not only for purposes of responsible innovation, but also for the quality of innovative projects, high-quality communication between innovation team members and other involved actors can be desirable (Flipse and Van der Sanden 2014). For instance, critical and more inclusive communication, both in industrial and academic environments, may help teams clarify project goals

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and expectations, anticipate success chances and risks, and respond to a greater variety of considerations. Even and perhaps especially during early phases of project management, i.e. what is known as the 'front-end' development phase, communication is regarded as essential for orienting and streamlining projects from the very beginning (Kim and Wilemon 2002; Poskela and Martinsuo 2009). This phase of innovation project management thus provides an opportunity to explore whether such communication can also provide means to discuss aspects, such as complexity, that potentially support the qualities of reflexivity and responsiveness.

How to adopt a project during its front-end development phase is a subject of debate (Bosch-Rekveldt et al. 2011), and by extension it remains the question what constitutes good and relevant communication in project management (Poskela and Martinsuo 2009). It is thus not immediately clear how aspects relevant to responsible innovation could be effectively integrated during this phase of innovation. Research has shown that innovators often do not explicitly consider aspects other than scientific and technological content (Flipse 2012), suggesting opening up communication in a manner consistent with responsible innovation may not be a simple or straightforward proposition. Additionally, in many innovative projects, time and cost overruns continue to occur regularly. Some research even shows that up to 85% of projects fail to meet time and budget goals (Shenhar and Dvir 2007). Typical approaches for increasing success chances – in the sense of reaching set goals within estimated time and budget – can be found in the use of support tools for project *organization*, such as PRINCE2 or SixSigma. In addition, tools exist that support project *quality*, such as the Wageningen Innovation Assessment Toolkit (WIAT, Fortuin and Omta 2007). The latter kind of tools can help innovative project teams to monitor the quality of on-going innovation projects based on identified relevant Key Performance Indicators (KPIs) that could help in determining possible ways to improve running projects while they are running. Importantly, project complexity aspects relating to e.g. technical (content), organizational (management) or external (socio-economic) aspects (*cf.* Bosch-Rekveldt et al. 2010) can constitute parts of such identifiable KPIs.

Still, these existing tools and methods usually do not explicitly contain aspects relevant for responsible innovation. Moreover, both organizational and quality monitoring tools are useless without communication about their implications on daily practice, feeding back into future research and development (R&D) choices. But tools specifically aimed at stimulating and supporting such functional communication, about quality-related aspects appear to be much less developed.

Within the social sciences and humanities, much research is currently being conducted aimed at stimulating interaction within teams and between team members and outsiders, particularly aimed at enabling responsible innovation (Balmer et al. 2016; Fisher et al. 2015). Insights from these fields could be useful for the field of innovation management, especially in relation to communication within and between members of organizations (cf. Blok, Hoffmans, and Wubben 2015). Midstream Modulation (MM) appears to be one of the promising frameworks with accompanying methods from the social sciences and humanities, and these have been extensively tested in both academic (Fisher and Mahajan 2006; Lukovics and Fisher 2017; McTiernan et al. 2016; Schuurbiers 2011; Conley 2011) and industrial (Flipse, Van der Sanden, and Osseweijer 2013; Phelps and Fisher 2011) settings.

Within collaborative approaches to MM, technical actors (scientists, engineers, project leaders, technicians, etc.) interact on a regular basis with a so-called 'embedded humanist', i.e. a critical outsider, usually from a social science or humanities field, who develops interactional expertize with innovation-related aspects, in order to understand and build capacities for responsible innovation (Fisher and Rip 2013; Fisher and Schuurbiers 2013). Ideally, during the collaboration between the technical actor and the critical outsider, the two 'co-create' innovations that are not only technologically state-of-the-art but are also developed – and possibly produced and deployed – more responsibly. MM in that sense supports creative and out-of-the-box thinking by technical actors, by expanding their considerations beyond scientific and technological aspects, thereby also improving the quality of their work.

Usually innovation projects are characterized by a high degree of social complexity, and actors involved suffer from bounded rationality (Kahneman 2003; Simon 1982): they simply cannot fully grasp the complexity and dynamics of their projects. Discussions with outsiders could help them better cope with this in practice (Flipse and Van der Sanden 2014). Even though MM focuses on interaction and communication during R&D phases of innovation, these interactions could in theory be relevant for the implementation of innovations in practice. More specifically, insofar as MM facilitates interactions with an external party (in this case, the embedded humanist as a critical outsider) it is possible that such interactions can help unravel innovative project complexity, further supporting both the quality of innovative projects and the consideration of aspects for responsible innovation.

Paper aim and structure

Accordingly, the research reported on here explores to what extent collaborative approaches to MM can be synergistically used to stimulate communication about aspects related to innovation project complexity, in addition to aspects related to responsible innovation, for which it has been used solely in earlier research. Acknowledging the possibility and utility of MM in corporate R&D (*cf.* Flipse, Van der Sanden, and Osseweijer 2013), we aim to study whether a similar approach may also be functional in other innovative contexts, more 'downstream', i.e. in stimulating and enabling communication in innovative project management that concerns *implementation* of technology in *practice* and the aspects that may make such implementation complex.

As such, we ask the question: what is the effect of stimulating communication about project complexity, including responsible innovation elements, using MM during early phases of industrial innovation management? Using small explorative case studies in engineering and construction within the Dutch process industry, we hope to demonstrate the possibility and utility of this approach on communication for responsible innovation, during the front-end development phase in early project management.

This paper is structured as follows: first, we place our study in a theoretical framework in which we elucidate the concept of MM and the context in which we will apply MM. Next, we present the method we applied to test the utility of MM in the Dutch process industry and the case study used in this study. We then present the results of our investigation. We conclude with a discussion of the value of MM for supporting communication in the context of innovation projects during the implementation phase of innovations.

Theoretical background

Midstream modulation

MM was first introduced by Fisher and Mahajan (2006) using a collaborative approach that later became known as Socio-Technical Integration Research (STIR), i.e. research on the possibility and utility of the integration of social and ethical aspects in technological development trajectories (Fisher and Schuurbiers 2013). The 'midstream' regards the focus on the governance of R&D in a societal context. In contrast to setting rules, requirements regulations on *what* to research (upstream governance), or enhancing implementation (downstream governance) by e.g. considering interaction with the end-users, the midstream focuses on the researchers' considerations and actions during their daily practice (Fisher, Mahajan, and Mitcham 2006). The term 'modulation' refers to the possible influence of these researchers' reflexive considerations and goal-directed actions on technologically innovation pathways (Fisher, Mahajan, and Mitcham 2006).

The STIR approach to documenting and facilitating MM stimulates innovators on their working floor to explicitly consider social and ethical aspects and to act upon those. This is done through regular and sustained interaction between innovators and a critical outsider. Usually, this outsider is someone who only becomes familiar with an organization's particular socio-technical regime after becoming 'embedded' within in (Fisher and Mahajan 2006, 2010). Due to his/her initial unawareness of the socio-technical regime, the outsider is likely to exhibit, possibly unintended, rule-breaking behavior (Van de Poel 2000). This 'probing' (Fisher 2007) and 'disruptive' (Wynne 2011) quality can be valuable for enhancing responsiveness during the development of products and processes, e.g. by stimulating creativity and out-of-the-box thinking (Fisher and Mahajan 2010). One condition for this enhancement to occur is that a 'collaborative space' (Flipse et al. 2014) be created in which critical comments by the outsider are both valued and appreciated.

Making the STIR approach to MM relevant for the process industry

While the STIR approach to MM has been demonstrated to work in laboratory and other environments to stimulate responsible innovation practice, the approach also has its limitations. Predominantly, MM can be considered difficult to implement in practice due to its long run-time, i.e. 12 weeks of regular interaction between the outsider and the innovator (cf. Felt, Fochler, and Sigl 2018). In innovation practice, this can be considered (too) long in terms of time investment and willingness to participate by innovation practitioners. We hypothesize therefore that the period can be shortened if the outsider is more familiar with the aspects of project management that may be relevant for the innovator. Then the outsider can more readily understand the aspects that encompass and influence the innovator's daily decision practice, and more quickly provide feedback that may be valuable for the quality of the running project. Such quality related aspects could e.g. be found in the Technical, Organizational and External (TOE) complexity framework, developed by Bosch-Rekveldt et al. (2011). We use the term 'project complexity' as collective term for all the elements within a project that could raise difficulties during the project's execution.

The TOE-framework helps to operationalize complexity. It contains 47 aspects, on three (TOE) levels. Both implicitly and explicitly, these aspects contain broader socio-ethical and socio-economic aspects, such as external stakeholders, political influences,

internal strategic pressures and interdisciplinary differences, that are potentially relevant to responsible innovation. They also contain aspects relevant to project management, for instance such as the alignment of project goals, uncertainties, duration, language, contracts, resources, location, competition, risks, etc. We refer to the original work of Bosch-Rekveldt et al. (2011) for the full list of elements. Considering that the aspects within the TOE-framework are identified within the context of the process industry, we further hypothesize that the framework could be relevant for giving the outsider an idea of which aspects to focus on in their interaction with innovators and, in this case, with project managers. Project management literature provides little to no assisting tools for project managers to assess the complexity footprint of their projects. We, therefore, test whether the topic of complexity can be a starting point for discussions with the innovators following the MM approach.

Although the framework contains 47 complexity elements, we do not assume that the project's complexity is a summation of these 47 elements. Also, interrelations between the elements are not ruled out, and some aspects may be irrelevant in the context of use even though they are in the model.

Front-end development phase

In this study, we focus on the 'front-end' development phase of projects, when some degree of steering and adaptation is still possible. This phase is considered of great importance for eventual project performance (Merrow 2011; Morris, Pinto, and Söderlund 2011). It is understood in the project management literature as the first phase within the life cycle of a project: starting at the moment that the ideas for a project's execution are conceived and ending at the moment the final decision to finance and run the project is made (Williams and Samset 2010).

The main objective in this phase is to ensure that the 'case owner' or project leader obtains sufficient knowledge, in order to decide at the moment of the final investment decision whether or not a project is worth investing in. In this phase – while the project exists only on paper – the front-end development stage provides the opportunity to make high-impact changes at relatively low cost by identifying and addressing the project's potential complexities before the final investment decision, thereby providing ample opportunity for realistic planning and execution. Communication with relevant stakeholders, as we have argued above, is crucial to create and realize such a realistic planning and execution. Aspects within the TOE-framework can be valuable input during this phase, and interaction with an outsider using the MM-approach can further help to explicate relevant TOE aspects and help to solidify the plans.

Methods

Data acquisition: using a modified MM approach

We use a qualitative research method to investigate project managers' considerations and actions with regard to their projects' complexity, based on a slightly modified STIR method for documenting and enhancing MM. The method is changed in two fundamental ways, both of which help us adapt to a less forgiving and more fast-moving industrial context. First, in this study the STIR method aims not only to achieve inclusion of

considerations on social and ethical aspects but also to achieve inclusion of considerations and actions on project complexity aspects as identified in the TOE-framework. These include, but are not limited to, social and ethical aspects. As such, we further support the 'embedded humanist' in highlighting relevant aspects more quickly. Second, the duration of the method is shortened from 12 weeks to five weeks of interactions – and three weeks of STIR protocol exercises – between the outsider and the project manager. As such, we explore the possibility of facilitating MM in a more compressed timeframe.

Two additional features of our study make it relatively distinct and are important to note: first, instead of focusing on R&D projects in emerging technologies such as nanotechnology and synthetic biology, as most STIR studies have done, we focus on the context of engineering and construction projects in the Dutch process industry. Finally, the field work for this research was not performed by a scholar from the social sciences, but by a critical outsider with a technical background (similar to McTiernan et al. 2016), in this case in both communication and technical process management, i.e. the second author of this paper.

The other aspects of the STIR approach to MM were left intact. Namely, the data for this research is acquired in consecutive weekly exercises using the semi-structured decision protocol (Fisher 2007). We involved three project leaders of three different innovation projects in the process industry. Each project leader was interacted with five times: during an introductory pre-study interview, three protocol exercises (also referred to as progress interviews) and one post-study interview. The first interview is focused on gaining insights in the project and how the project manager is currently coping with the project's complexity. The final interview addressed similar aspects, allowing for a comparison of the pre- and post-study interviews to identify possible changes over time. The post-study interviews were also used to assess the participants' perceived usefulness of their engagement with the critical outsider.

The three decision protocol exercises were based on three components. First, as is the general practice with STIR, the content of the previous interview. Second, the 47 complexity elements of the TOE framework, which are used by the critical outsider to gain a view of the project's complexity as a starting point for the future interviews. Third, the semi-structured STIR 'decision protocol' (Fisher 2007). This protocol is used to map four different components that make up a decision by an innovator: the possible project *opportunities*, the *considerations* that the innovator must take into account, possible *alternatives* that can be used to reach the goals, and anticipated *outcomes*. The different perspectives used in this decision protocol are originally the technical and social perspectives (Schuurbiers and Fisher 2009), but since this study is not performed in an academic, but in a corporate environment, an economical perspective is added to the decision protocol (*cf.* Flipse 2012).

Data analysis

Following the STIR method, we identify three different kinds of 'modulations': *de facto*, *reflexive* and *deliberate* modulations (Fisher and Mahajan 2010; Fisher, Mahajan, and Mitcham 2006). We consider *de facto* modulations as elements that shape the complexity of a project, such as time pressure, technical requirements, and also other aspects that are included in the TOE framework. *Reflexive* modulations are observed when the project

Table 1. Semi-structured interview protocol for the pre- and post-study interviews.

1.	Please tell me more about your project. What are the project goals? What happened in the previous weeks?
2.	Could you tell me about the origin of this project / What is the motivation for starting?
3.	What is the planning of the project?
4.	How is the project funded? Is there cooperation with other companies?
5.	Which stakeholders are involved in this project? Could you sketch the project organization?
6.	What are currently the biggest challenges?
7.	How is determined which activities have to be conducted in the front-end development phase?
8.	What is your role within the project organization. Who has the final saying regarding the determination of which activities to conduct in the front-end development phase?
9.	Which considerations play a role in these progress decisions?
10.	What are the criteria for assessing whether or not the project is a success?
11.	How is the project reviewed during the project process? Who is involved?
12.	Could you elaborate on the role of the TOE complexity aspects in your daily work?
13.	What role does your own personal opinion on complexity issues play in determining the future direction of a project?
14.	Would it be 'good' for the quality of project management to increase attention on complexity implications? How, why?
15.	What are your expectations for the next 4 weeks, if any? (only pre-interview)
16.	Do you consider this method as something extra, over and above work? Or rather as something that is part of your work?
17.	Do you have any further questions, or are there issues that have not been addressed?

manager explicitly demonstrates reflection on the identified *de facto* aspects, e.g. when consequences of decisions are discussed or elaborated on. *Deliberate* modulations are observed when the project manager explicitly states to plan or have carried out actions based on *reflexive* aspects and insights, e.g. when he/she specifically includes certain aspects that were discussed during the protocol exercises in order to improve project performance.

By monitoring these modulations over time, changes in awareness of complexity can be identified. These are presented in the results section as a 'narrative', i.e. an example of a conversation between the outsider and the project leader. In addition, differences in answers to questions during the pre- and post-study interviews generate insights into changes in the project manager's perception of complexity (Table 1). Also, the post-study interview is used to further reflect on the functionality of the approach.

The recorded interviews, roughly 15 hours in total, were analyzed by re-listening to them, transcribing the elements that highlight indications of modulations including reflexive awareness of complexity. This resulted in roughly 17,000 words of *ad verbatim* transcripts that were open-coded using modulations and TOE aspects as starting points. Considering that the interviews were conducted in Dutch, and the data presented below are in English, we asked the participants check the translated texts for accuracy, preventing possible misinterpretations by the authors. The authors together reflected on the coding and interpretation until consensus was reached on their relevance and implications with regard to the research questions and objectives.

Case descriptions

Due to confidentiality agreements, the exact names and project descriptions cannot be revealed. As such, the three participants remain anonymous, and we refer to them as P1, P2 and P3. Their projects can only be described in a general way, as follows.

Case 1 is a feasibility study to determine whether it is possible to increase the flow capacity of a certain substance through a pipe to another plant nearby, which purchases

this substance. The owner of the pipe, for whom P1 works, initiated the project. The focus of the project is on increasing the flow capacity through the pipe by removing a bottleneck: the flow meters. A flow meter is used to measure the amount of fluid that passes through a pipe. Once the flow meter is replaced with a larger one, the plant should be able to deliver more substance to the client. The costs for this project are roughly €300,000. At the start of the interviews the project was in the front-end development phase. For P1 this project is one of several he is responsible for. The project was consequently not full-time managed by this project manager, and has no full-time project team.

Case 2 concerns the engineering and construction of a new installation on a client's plant site. This installation needs to be engineered, constructed and installed. The construction part is likely to be done overseas. Including the execution, the cost for this project is estimated to be €100,000,000. The interviews are conducted with the full-time project manager of this project, P2.

Case 3 concerns an earlier engineering project that had already been largely completed for a certain client. However, due to external influences, such as increasing oil prices, the client determined that the originally engineered project was too expensive. Since the project included several aspects that still had to be performed, the project had to be resized. Including the execution, the costs for this new project are approximately €3,000,000. The interviews are conducted with P3, the full-time project manager of this project.

Results

Below, first an example is given of a narrative that shows how communication between the project leader and the outsider progresses. We highlight changes in awareness of TOE complexity aspects during the consecutive interviews, and between the pre- and post-study interviews. We also document observed modulations. Second, we present the integrated results of the analysis of all three participants' considerations and actions with regard to their projects' complexity. Third, we provide the participants' reflections on the modified STIR approach to MM and thereby the usefulness of the discussions with a critical outsider.

Micro-level results: a narrative with a project leader on complexity issues

During the pre-study interview with P1, the following was discussed with the critical outsider (CO) in light of the project's complexity footprint:

> Critical outsider (CO): What complexity elements do you recognize in your project?
> P1: Hmm, that is a difficult question. Obviously the type of [substance]. Hmm, also a bit of stakeholder management: in the sense of how much importance is placed on a project or criterion. Also in the element 'time' I reckon a complicating factor. Especially if this date is a hard deadline. This interferes also with budget: If the plan will not be approved because the business unit is out of budget for this year, the project will automatically be delayed. [Pre-study interview, P1 9 October 2014]

It appears that P1 is able to identify several elements that could cause difficulties, including technical complexity, organizational complexity and external complexity. Yet mostly on a

general level, without discussing further context and practical examples. During the three exercises that followed and that took place before the post-study interview, several more complexity elements were identified and discussed. In the post-study interview a similar question was asked:

> CO: Could you indicate what elements you consider to cause difficulties in your project?
> P1: Surely the lack of input. […] I was asked to start this project and only along the way it became clear what the project really entailed. This has resulted in two extra budget requests just for finalizing this study phase. Furthermore, the special type of substance and clarity of the delivery date, although that is also a part of input of course. [Post interview, P1 6 November 2014]

After the interactions with the outsider, P1 does not state many more elements that contributed to the project's complexity, but does describe these elements more elaborately, and with practical context. He does indicate that over the last four weeks the project has become clearer to him. He reflected on the project as follows:

> P1: All considering, this is an interesting project. Seemingly it is just a minor adjustment to an existing installation. It is not difficult, it is not large, on first sight not that complex, but see how many elements are involved! [Post interview, P1 6 November 2014]

It appears that during the exercises, P1 became more aware of what his project entailed. He recognizes that the project incorporated more elements that complicate the project than he first envisioned. To us, this indicates an increase in the depth of his considerations regarding the project's complexity.

To provide insights in how such awareness may be generated, we identify and discuss instances of the three modulations: *de facto*, *reflexive* and *deliberate*. An example follows of one of these discussions regarding the impact of the project interfering with the existing site.

> CO: The project is an adjustment to an existing site. Is this a topic of concern? Why?
> P1: Yes, there is the project risk of working behind one valve. Imagine if it leaks. Then the whole project needs to be cancelled. Of course, we assume this is not the case, but if it does, it is a serious issue. [Progress interview 1 P1, 16 October 2014]

P1 has the task to do a feasibility study on whether it is possible to deliver more substance through a pipe between his organization's and a customer's plant. The *de facto* modulation is acknowledged through the CO's asking about possible implications as result of the project's interference with the existing site. P1 recognizes this complexity element and directly also presents a *reflexive* followed by a *deliberate modulation*. The *reflexive* modulation is P1's realization that the project needs to be canceled in case of a leak. The *deliberate* modulation regards his implicit decision based on this insight: P1 assumes all will be alright and does nothing. The CO challenges this in the next discussion:

> CO: Do I understand correctly that the work will be conducted behind one valve?
> P1: I did discuss this with the team [last week]. They told me that not too long ago some repair work had been executed behind this valve, and although this is not a guarantee, it did not leak. See, if this is not the case we get a completely different situation. In that case, we have to take completely different measures. However, for the time being we assume that this will not be a problem. [Progress interview 2 P1, 23 October 2014]

As the CO learned, the previous discussion had in fact triggered P1 to elaborate on this topic with his team, which is a *deliberate* modulation that encouraged team communication. Again, when asked about it, P1 displays concern about the topic as a potential threat for the project (and below, for the workers and for the company), though he remains passive towards it. Yet the CO continues to challenge P1 on this issue, recognizing it as of possible relevance for responsible innovation (i.e. anticipation of future effects):

CO: Will you test to see if the valve leaks?
P1: In case you have everything prepared and it turns out to not to be possible?
CO: Yes.
P1: Well, uhm, I don't know. I don't think we will do that in advance, but you should … hmm, yes. If I'm correct, perhaps, I'm just thinking, that bypass, that is empty right?
CO: Would that be an opportunity?
P1: Well I assume that it is empty. Though I'm wondering: you can flush that pipe with air. Then you would have an extra valve over there. [points at a drawing of the installation] Could you measure it over there then? Yes. No. You should still need to check whether everything is indeed gone. It needs to be measured. See, my men will be completely suited up, so that is not the problem, but in case of just the slightest emission we would have to report this to the government, which you don't want to. […] Fine, this is an important issue, I will take this up to the expert. [Progress interview 2 P1, 23 October 2014]

It appears that the issue, which was first assumed to be 'not a problem', transformed into 'an important issue', which P1 deliberately addresses by bringing the issue up with the company's designated expert on this subject. The next week, the discussion continues:

CO: Last week, you planned to discuss the issue of the valve with the expert. How did this go?
P1: Yes, I have discussed this with the expert and he considers it a low risk. It is absolutely not expected that the valve will leak. For me it does however remain a conditional issue. […] I will consult the expert again whether it is worthwhile and possible to check this in advance. It is an important issue, though here on site I reckon that they do not consider it likely to be leaking. [Progress interview 3 P1, 30 October 2014]

After one week, when asked by the CO about this issue again, P3 reports that he has taken this up with an expert, following the discussion the previous week, demonstrating another *deliberate* modulation.

Meso-level results: integrated results of all participants

We also investigated the remainder of the interviews for other *de facto*, *reflexive* and *deliberate* modulations, but for the sake of readability and to save space we refrain from reproducing these here in narrative form. Instead, we report quantitatively that P1 demonstrated eight (8) other occasions [nine (9) in total] of sequential *de facto*, *reflexive* and *deliberate* modulations similar to that sequence presented in the narrative above, and P2 demonstrated this on four (4) occasions. We also observed that the *deliberate* modulations generally concerned the initiation of communication with other team members or other outside experts, and that *deliberate* modulations tended to involve some sort of TOE-framework complexity element. Furthermore, the topics of such initiated communication tended to cover all three Technical, Organizational and External complexity aspects, suggesting that both technical elements and those more obviously associated with responsible innovation were discussed together.

No further results for P3 are presented here. This is because during the research period of five weeks, the project endured some developments that resulted in its slowing down. During the first exercise it became clear that although the client still required a final proposal for the resized project, the client did not have the intention to execute the project anymore at that time. Therefore, instead of having one pre-interview, three exercises and one post-interview, this case consists only of one pre-interview, one exercise and one post interview. Consequently, little can be stated about P3's considerations and actions with regard to his project's complexity, since there were no practical developments that could be monitored.

Regarding the difference between pre- and post-study interviews, the analysis shows that all three participants already show awareness of complexity elements at the beginning of the interview series. Answers given by P2 and P3 are comparable to the answer to the first questions as given by P1 in the narrative presented above. Excluding P3 from the analysis (since no progress during the project was made), not much increase in awareness on the *variety* of project complexity aspects can be demonstrated in this study for P1 and P2 through analysis of the pre- and post-interviews. However, the perceived *depth* of complexity regarding identified practical aspects does vary, as demonstrated by changes evident in *de facto*, *reflexive* and *deliberate* modulation sequences.

Macro-level results: utility of the compressed MM approach

Below we present the answers of the participants during their post-study interviews on the question whether they found the conversations over the past five weeks useful.

P1: Yes. […] The questioning of the assumptions that were made, and uhm … Look, we have some affairs that sort of follow a set of unwritten rules. Then it is refreshing to have someone from outside, who asks the critical questions: why is that? And: is that right?

P2: Well, it is always useful to have these discussions. By talking about it you are forced to think about the project yourself, which results in thoughts like: Oh yes, I have to put that on paper. […] However, I cannot state that I determined my decisions in the last few weeks solely based on my discussions with you. It is just more in general: you discuss a subject and then you realize that you make something more clear to the client for example.

P3: Well, it could be. Yes, it might trigger you to think about aspects of your project you would normally not think of.

This overview shows that the perceived usefulness differs among the participants. P1 considers the discussions to be useful. P2 is more reserved, stating that discussions in general are useful, but changes in practice cannot be solely attributed to his interactions with the CO. P3 considers that the discussions might be useful, but it is important to note that he was not fully engaged in the study since his project was postponed and showed no further practical reflections on the value of his interaction with the CO.

Discussion

Implications of this study

The results of this study show that the MM approach, in a shortened format and with specific support of the TOE complexity aspects framework, can indeed be used to

support and even to catalyze communication within and between innovation teams during the front-end development of projects in the process industry. Various occasions of *deliberate* modulation can be observed, indicating explicit action by an innovator based on reflexive insights discovered during the semi-structured interactions with the critical outsider. Moreover, the participants who participated in the full extent of this study (P1 and P2) claim to have appreciated the discussions with the outsider. This is important because it suggests that our modified MM approach can be used to support efforts aimed at responsible innovation more quickly than previously documented and with fewer resources. Indeed, one of the criticisms against the STIR approach to MM has been that it is time-intensive (e.g. Felt, Fochler, and Sigl 2018).

Similar to published STIR studies aimed at inducing MM (Fisher 2007; Fisher and Mahajan 2006; Fisher and Schuurbiers 2013, Flipse et al. 2012; Flipse, Van der Sanden, and Osseweijer 2013; Lukovics and Fisher 2017; McTiernan et al. 2016; Schuurbiers 2011), our modified STIR approach facilitated reflection on broader societal considerations as well as specific actions, although there appears to be a higher frequency of the former than of the latter. In contrast to these studies, however, most of the cases of *deliberate* modulation that we identified here also concerned aspects related to *communication*, e.g. *deliberative* action in the form of scheduling a meeting or to discuss the identified complexity element with an (internal or external) expert. This appears to be different from these past studies, which tend to emphasize documenting changes in the practical execution of the technical work being conducted.

As in similar studies, the question remains whether the observed modulations would also have occurred without the explicit involvement of the critical outsider. The modulations that were documented could be considered the result of a complex combination of the participants' own experience and intuition, discussions with colleagues and interactions with the critical outsider. It is impossible to assess the explicit effect of the critical outsider or to attribute the observation of modulations solely to the involvement of the outsider. Still, the narrative with P1 shown above does indicate that repeated interaction with the outsider deepens the discussions about complexity related aspects; it also suggests that the final actions by the innovator would not have occurred without the outsider's persisting input. Other observed modulations are less clear in this regard and could also be considered the result of the participants discussing the project with a colleague, or simply the result of participants' own experience and intuition. Yet even in these cases, it appears likely that this form of outsider involvement led to *earlier* consideration of broader aspects that would have been considered anyway, or to more *thorough* consideration and even investigation of such aspects.

Study limitations

The limitations of this study primarily concern the explorative nature of this research, and the length of the research period. A clear limitation of this research is the low number of cases that have been included. With just three cases, no conclusions can be made regarding the generalization of our results towards the broader context of innovation management. Another limitation of the research is the number STIR exercises that were conducted per participant. Prior MM research contained 12 weeks worth of such interactions per participant. In this study, only three per participant were conducted. This possibly severely

limited the number of modulations that could be identified. On the other hand, the fact that we were able to identify deliberate modulations within such a short period, demonstrates the value of the TOE framework as an aid for helping the critical outsider get to relevant aspects more quickly than in earlier MM work without such a framework: namely, in earlier MM studies, modulations are generally observed later than in three weeks' time (Flipse, Van der Sanden, and Osseweijer 2013; McTiernan et al. 2016; Schuurbiers 2011).

Furthermore, this research assumes that the assessment by the project manager of the project's 'complexity footprint' (cf. Gransberg et al. 2012), insofar as this is explicitly done on a regular basis, is influenced by the regular daily routine of this manager. In such situations, regular daily affairs may not always be explicitly questioned by the project manager himself. In this context, an outsider may be able to pick up on and to challenge social relations and unconscious assumptions that are taken for granted, hereby increasing project managers' awareness about his own project. However, we did not explore this systematically using the empirical data.

Conclusion and recommendations

This paper aimed to answer the question: what is the effect of stimulating communication about project complexity, including responsible innovation elements, using MM during early phases of industrial innovation management? The effect appears to be twofold. First, the MM method was shown to be a functional tool for identifying and assessing project managers' considerations with regard to their projects' complexity. The method also proved to be useful for assessing project managers' efforts to cope with their projects' complexity, constituting an extension of the initial MM approach. Second, our modified version of STIR as an intervention method appears to enhance both *reflexive* and *deliberate* forms of MM, even though we reduced the interaction time from 12 weeks to 5 weeks.

Regarding responsible innovation aspects, our results demonstrate the effectiveness of our approach for all four elements (reflection, responsiveness, inclusion and anticipation). Thus, the observed *reflexive* modulations indicate that the modified approach supports reflection; and the *deliberate* modulations are indications of responsiveness to external socio-ethical and socio-economic pressures. We also showed that most *deliberate* modulations are about initializing communication, and hence relate to the inclusion of other viewpoints, in order also to anticipate further downstream effects and minimize risks. While we do not claim here that the presence of a critical outsider using MM is sufficient to make a project 'responsible', we do suggest that this can help move projects in directions intended by responsible innovation literature and policy (Fisher and Rip 2013; Rodríguez, Fisher, and Schuurbiers 2013).

Our study thus offers support for enhancing the capacity of interventions aimed at responsible innovation in two key respects: first, it shows that MM of innovation projects can be enhanced in a compressed timeframe; and second, it shows that a critical outsider can be aided by a framework (in this case for reflecting on project complexity) for more quickly identifying topics for consideration and reflection on the part of the innovator.

Various recommendations for future research can be proposed, in order to generate results relevant to a larger innovation management context. For example more case studies in a larger coordinated set of studies could produce more generalizable results.

Also, the study could be expanded beyond front-end development, to include project implementation/execution stages. We hope future research can help explore the full potential of early and strategic communication in responsible innovative project management.

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References

Balmer, A. S., J. Calvert, C. Marris, S. Molyneux-Hodgson, E. Frow, M. Kearnes, K. Bulpin, P. Schyfter, A. Mackenzie, and P. Martin. 2016. "Five Rules of Thumb for Post-ELSI Interdisciplinary Collaborations." *Journal of Responsible Innovation* 3 (1): 73–80.

Blok, V., L. Hoffmans, and E. F. M. Wubben. 2015. "Stakeholder Engagement for Responsible Innovation in the Private Sector: Critical Issues and Management Practices." *Journal on Chain and Network Science* 15 (2): 147–164.

Bosch-Rekveldt, M., Hermanides, S., Mooi, H., Bakker, H., and Verbraeck, A. (2010). The Influence of Project Front-End Management and Project Complexity on Project Success: A Contingency Approach in Project Management. *Proceedings of Project Management Institute Research and Education Conference*, 11-14 July 2010, Washington DC, USA.

Bosch-Rekveldt, M., Smith, J., Mooi, H., Bakker, H., and Verbraeck, A. (2011). The application of Value Improving Practices: Team Integration Pays Off!. *Proceedings of EURAM 2011*, 1-4 June 2011. Tallinn, Estonia.

Conley, S. N. 2011. "Engagement Agents in the Making: On the Front Lines of Socio-Technical Integration." *Science and Engineering Ethics* 17 (4): 715–721.

Felt, U., M. Fochler, and L. Sigl. 2018. "Imagine RRI. A Card-Based Method for Reflecting on Responsibility in Life Science Research." *Journal of Responsible Innovation*. doi:10.1080/23299460.2018.1457402.

Fisher, E. 2007. "Ethnographic Invention: Probing the Capacity of Laboratory Decisions." *NanoEthics* 1 (2): 155–165.

Fisher, E., and R. Mahajan. 2006. "*Midstream Modulation of Nanotechnology in an Academic Research Laboratory*." *Paper presented at the ASME 2006 international mechanical engineering congress and exposition*.

Fisher, E., and R. L. Mahajan. 2010. Embedding the Humanities. In Engineering: Art, Dialogue, and a 10 Laboratory (M.E. Gorman). Trading Zones and Interactional Expertise: Creating New Kinds of Collaboration, 209. MIT Press Scholarship Online, August 2013.

Fisher, E., R. L. Mahajan, and C. Mitcham. 2006. "Midstream Modulation of Technology: Governance from Within." *Bulletin of Science, Technology & Society* 26 (6): 485–496.

Fisher, E., M. O'Rourke, R. Evans, E. B. Kennedy, M. E. Gorman, and T. P. Seager. 2015. "Mapping the Integrative Field: Taking Stock of Socio-Technical Collaborations." *Journal of Responsible Innovation* 2 (1): 39–61.

Fisher, E., and Rip, A. (2013). Responsible Innovation: Multi-Level Dynamics and Soft Intervention Practices. In *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society*, edited by R. Owen, J. Bessant, and M. Heintz (165–183). Wiley.

Fisher, E., and D. Schuurbiers. 2013. "Socio-technical Integration Research: Collaborative Inquiry at the Midstream of Research and Development." In *Early Engagement and new Technologies: Opening up the Laboratory*, 97–110. Dordrecht: Springer.

Flipse, S. M. 2012. Enhancing Socially Responsible Innovation in Industry: Practical Use for Considerations of Social Ethical Aspects in Industrial Life Science and Technology. *PhD Thesis*.

Flipse, S. M., and M. C. A. Van der Sanden. 2014. A Role for Communication Professionals in Support of Responsible Innovation Practices. *Proceedings of the 13th International Public Communication of Science and Technology Conference*, 5–8 May 2014, Salvador, Brazil.

Flipse, S. M., M. C. A. Van der Sanden, and P. Osseweijer. 2013. "Midstream Modulation in Biotechnology Industry: Redefining What is 'Part of the Job' of Researchers in Industry." *Science and Engineering Ethics* 19: 1141–1164.

Flipse, S. M., M. C. A. Van der Sanden, M. Radstake, J. H. De Winde, and P. Osseweijer. 2014. "The Wicked Problem of Socially Responsible Innovation." *EMBO Reports* 15: 464–464.

Fortuin, F. T. J. M., and S. W. F. Omta. 2007. "The Dynamics of the Strategic Network Relations Between Corporate R&D and Business: A Longitudinal Analysis in a Large, Technology-Based Multinational Company." *Journal on Chain and Network Science* 7 (2): 95–108.

Gransberg, D. D., J. S. Shane, K. Strong, and C. L. del Puerto. 2013. "Project Complexity Mapping in Five Dimensions for Complex Transportation Projects." *Journal of Management in Engineering* 29 (4): 316–326.

Kahneman, D. 2003. "Maps of Bounded Rationality: Psychology for Behavioral Economics." *American Economic Review* 93 (5): 1449–1475.

Kim, J., and Wilemon, D. 2002. Strategic Issues in Managing Innovation's Fuzzy Front-End. *European Journal of Innovation Management*, 5(1): 27-39.

Lukovics, M., and E. Fisher. 2017. "Socio-technical Integration Research in an Eastern European Setting: Distinct Features, Challenges and Opportunities." *Society and Economy* 39 (4): 501–528.

McTiernan, K., B. Polagye, E. Fisher, and L. Jenkins June. 2016. Integrating socio-technical research with future visions for tidal energy.

Merrow, E. W. 2011. *Industrial Megaprojects: Concepts, Strategies, and Practices for Success*, 1st ed. Hoboken, NJ: Wiley.

Morris, P. W. G., J. K. Pinto, and J. Söderlund. 2011. *The Oxford Handbook of Project Management*. Oxford: Oxford University Press.

Phelps, R., and E. Fisher. 2011. "Legislating the Laboratory? Promotion and Precaution in a Nanomaterials Company." *Methods in molecular biology (Clifton, N.J.)* 726: 339–358.

Poskela, J., and M. Martinsuo. 2009. "Management Control and Strategic Renewal in the Front End of Innovation." *Journal of Product Innovation Management* 26: 671–684.

Rodríguez, H., E. Fisher, and D. Schuurbiers. 2013. "Integrating Science and Society in European Framework Programmes: Trends in Project-Level Solicitations." *Research Policy* 42 (5): 1126–1137.

Schuurbiers, D. 2011. "What Happens in the Lab: Applying Midstream Modulation to Enhance Critical Reflection in the Laboratory." *Science and Engineering Ethics* 17 (4): 769–788.

Schuurbiers, D., and E. Fisher. 2009. "Lab-Scale Intervention." *EMBO Reports* 10 (5): 424–427.

Shenhar, A. J., and D. Dvir. 2007. *Reinventing Project Management: The Diamond Approach to Successful Growth and Innovation*. Harvard: Harvard Business Review Press.

Simon, H. A. 1982. *Models of Bounded Rationality: Empirically Grounded Economic Reason* (Vol. 3). Cambridge, MA: MIT press.

Stilgoe, J., R. Owen, and P. Macnaghten. 2013. "Developing a Framework for Responsible Innovation." *Research Policy* 42 (9): 1568–1580.

Van de Poel, I. 2000. "On the Role of Outsiders in Technical Development." *Technology Analysis & Strategic Management* 12 (3): 383–397.

Williams, T. M., and K. Samset. 2010. "Issues in Front-end Decision Making on Projects." *Project Management Journal* 41 (2): 38–49.

Wynne, B. 2011. "Lab Work Goes Social, and Vice Versa: Strategising Public Engagement Processes Commentary on: 'What Happens in the Lab Does Not Stay in the Lab: Applying Midstream Modulation to Enhance Critical Reflection in the Laboratory.'" *Science and Engineering Ethics* 17 (4): 791–800.