# CAUGHT IN THE VICIOUS CIRCLE OF IMPROVISATION: HOW DISTRICT HEATING CONSTRUCTION TEAMS COPE WITH RELIABILITY

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**Net-zero ambitions transform the built environment and lead to the introduction of alternative energy infrastructures such as district heating networks. While deploying such large and rigid pipelines in the crowded underground, newly established project teams face logistical uncertainties and technical complexities that often cause rework, delays, and damages. Little is known; however, about how such emerging project team organisations cope with these events. We hence aimed to describe and assess emerging teams' reliability coping processes. Specifically, we conducted twelve semi-structured interviews with engineers, managers, and foremen. We then analysed responses through a narrative analysis and by drawing on principles for mindful organising. This resulted in our conceptualisation of reliability practices as a self-reinforcing cycle, which steers toward favouring improvisational tasks. Unlike suggested by the literature, the cycle refrains from most formal planning and anticipation activities while fuelling the development of troubleshooting skills. This shows that emerging forms of organising may lack the required minimal structure to effectively anticipate but may nevertheless improvise well as they face expected and unwanted surprises.**

Keywords: district heating, improvisation, anticipation, high reliability organising.

# INTRODUCTION

The energy transition has led to the construction of new networks such as district heating (DH), which provide fossil-free energy in a viable way (Boesten et al., 2019; Lund et al., 2014; Werner, 2017). This new type of infrastructure connects multiple buildings within a municipal area to a centralised heat generation plant. The interconnected system enables the efficient sharing and distribution of heat, saves energy, and ultimately reduces greenhouse gas emissions (Lund et al., 2014). While the demand for these networks by cities may increase significantly (European Commission, 2022), their large rigid insulated pipelines must be deployed in between existing buried infrastructures, following new technological construction rules.

The construction of DH infrastructure assets typically takes place in densely populated districts (Persson & Werner, 2011). Due to the busy undergrounds in this space, district heating contractors need to think more mindfully than before about how a newly designed network fits within the existing underground conditions, workspace constraints, and logistical requirements. While conventional utility streetworks already present complex spatial puzzles, DH networks are even harder to build. For one, this is because their rigid pipelines cannot be flexibly bent around utilities that might be found on-site unexpectedly. Further, onsite adjustments to designed networks are also difficult because of long delivery times for pipeline materials, and more specialized engineering and welding procedures. Therefore, teams need to carefully design networks and create accurate bills of quantity upfront to supply sufficient materials on-site. Like in conventional streetworks, DH projects also face frequent design and process changes due to buried surprises in the underground, unfavourable weather conditions, and changing stakeholder demands. If not adequately anticipated altogether, such dynamics give rise to unwanted events in the construction process.

To better understand how organisations cope with uncertainties like these, construction management literature has made use of concepts from the High-Reliability Organising (HRO) literature (De Bruijne & Van Eeten, 2007; Mitropoulos & Cupido, 2009). Central to this are the notion of reliability and the principles of anticipation and containment. They allow organisations to function nearly error-free, under stable operating conditions. In 'normal modes' - i.e., where unwanted events are not being mitigated - organising takes place based on the foundation of a high degree of formalisation, characterised by a substantial corpus of rules, instructions, procedures, and policies (Bigley & Roberts, 2001). In 'emergency modes' these organizations use well-developed improvisation skills.

Emerging types of organisations - such as DH network project teams - are still developing the roles, structures, and responsibilities that underly 'normal modes' of HRO organising. This leads to the assumption that such teams also approach reliability strategies in ways that are different from HROs. Since the literature seems not to address how 'emerging' organisations pursue reliability, it becomes more difficult for CM researchers to describe how such new and upscaling organisations in the energy transition would grow effectively while maintaining their reliability.

This study, therefore, aimed to describe and assess the reliability coping processes of a DH project team organisation. As a starting point, we used the theoretical understanding that reliable organisations have processes in place to anticipate unwanted events and to contain the events that nonetheless occur (Weick et al., 1999). To analyse the structures and processes of reliability organising (Bakken & Hernes, 2006) we interviewed twelve practitioners in emerging DH organisations. Our narrative analysis that describes their lived experiences shows that DH project

teams are caught in a vicious circle: they employ formal planning and anticipation activities sparingly, leading to adeptness in improvisation owing to frequent unwanted events.

The remainder of the paper continues with an introduction to the HRO principles. We then explain how we used narrative analysis and HRO to describe the reliability coping of a DH network construction project team. Next, our results conceptualise the organisations' activities and decisions as the improvisation-enhancing cycle. We conclude by assessing the conditions that enhance or reduce reliability, some of which may hamper process improvements in the future.

## MINDFUL ORGANISING IN PROJECT ORGANISATIONS

Mindful organisational units achieve highly reliable processes through proactive behaviour towards avoiding unwanted and unexpected events (Weick, 2011). To achieve this, they need to establish structures and cognitive capabilities to: (1) pay continuous attention to discriminatory details that may derail ongoing operational processes (Barton & Sutcliffe, 2009), and (2) cope effectively with unwanted events (Weick et al., 1999).

Specifically, mindful organising adopts principles of containment and anticipation to handle unwanted events and prevent them from occurring in the first place. Containment principles enable teams to rebound from unwanted events mindfully and they consist of “commitment to resilience” and “deference to expertise”. Anticipation principles enable teams to manage tasks to sense and prevent unwanted events before they occur. These principles include “preoccupation with failure”, “reluctance to simplify”, and “sensitivity to operations” (Weick & Sutcliffe, 2007).

While the HRO literature shows that mindful behaviour is well developed within organisations in complex and high-risk environments (Weick & Sutcliffe, 2007), adverse circumstances may also significantly impact the performance of other organisation types. Roberts and Bea (2001) assessed that any organisation facing unwanted events can eventually benefit from HRO concepts. This also includes construction organisations (Olde Scholtenhuis & Doree, 2013).

Studies of mindful behaviour have so far focussed on organisational units such as house framing crews (Mitropoulos & Cupido, 2009), engineering teams at manufacturers (Gebauer, 2007), aircraft carrier crews, nuclear power plants crew, health care units, wildland firefighter crews (Weick & Sutcliffe, 2007), but also utility operator organisation (De Bruijne & Van Eeten, 2007; Gebauer & Kiel-Dixon, 2009) and general contractor (Enya et al., 2018). Many of these organisations have structures supporting five common operational functions (i.e., command, planning, operations, logistics, and finance/ administration) that furnish a sturdy foundation for the adoption of mindfulness principles (Bigley & Roberts, 2001).

In emerging types of organisations such as DH network project teams, however, such structures are still in development. Little is known about how this influences reliability. To address this gap, this study explored how teams try to execute DH projects reliably despite the infancy of their foundational functions. We specifically aimed to describe the activities, decisions and external conditions that determine how the teams cope with reliability.

## RESEARCH METHODOLOGY

We describe and assess the reliability coping process in a DH project team organisation by using a narrative analysis that interpreted the respondent's stories about their organising processes. This approach does not strive for generalisation but aims to uncover and reveal intricate patterns - in our case those influencing reliability organising.

We selected one of the few contractors in the country that is specialised in engineering, and building DH networks. Its teams design routes, engineer networks, order materials, schedule processes, and supervise activities such as trench excavating, pipe laying, welding, testing, and backfilling. We completed twelve interviews when saturation in the observed patterns occurred. The interviewed respondents were professionals (five engineers, three project managers, and four foremen) with overall twenty years of experience in the utility sector, but overall, with significantly less experience with DH-construction.

Interviews were held during a research internship of one author, which allowed him to create a mere informal setting and dialogue with respondents. In this setting, conversations developed about which actions and decisions professionals take when preparing or facing unwanted events during their projects. Following Clandinin and Connelly (2000), he prompted interviewees to share personal experiences and stories as narratives and through open-ended questions about these topics. His questions were, for example: “what kind of unwanted events do you experience in your DH projects?"; "can you explain to me how you experience this unwanted event and its impact?”; and "can you elaborate on what it involves for your team to resolve the unwanted event, should one arise?". We encouraged the respondents to share their experiences and insights freely by allowing further elaborations. We transcribed the interviews to later analyse the data.

To gain insights into the underlying meanings and structures within the organisation, we examined the transcribed stories and personal experiences. This first included a line-by-line analysis of the transcript to identify key themes, including ‘expecting unwanted events’, ‘normalising improvisation’, ‘restraint in formal planning’, ‘learning on the job’, ‘trained team structures’, ‘tailoring approach for context specificity’. It led to the identification of activities and decisions that either promote or hamper reliable performance.

A deeper understanding then surfaced about the meaning and significance of respondents' stories while we drew on the reliability literature. In specific, we compared the practitioners' logic to the theoretical ideal types of mindfulness principles. We found contradictions and confirmations between theoretical mindfulness principles and the developed narratives. This led us to re-iterate through the transcripts to identify how DH project contexts (environmental conditions and influences of third parties) influence the activities and decisions that teams perform to organise reliably. This led to a pattern of activities, decisions, and conditions that shape the reliability logic that is presented next.

## RESULTS

The narrative that captures the reliability logic can be described as an "improvisation-enhancing cycle" (Figure 1). It contains four connected activities and decisions (1-4), and four mediating conditions (I-IV).

This improvisation-enhancing cycle starts with (1) the recognition of the team that many types of uncertainties may impact their projects in the form of expected delays, rework, and damage. Being overwhelmed by this, but strengthened by a hands-on mentality, they start the design of a new project without using formal planning or anticipation processes. Subsequently, (2) the emerging situations present teams with 'expected surprises', which are then dealt with through improvising activities. Since these expected surprises occur frequently, the teams (3) have normalised their use of improvisations: with colleagues 'on the job' they discuss and reflect upon effective improvisation practices. This finally results in the teams (4) becoming well-equipped with cognitive skills to respond to surprises.

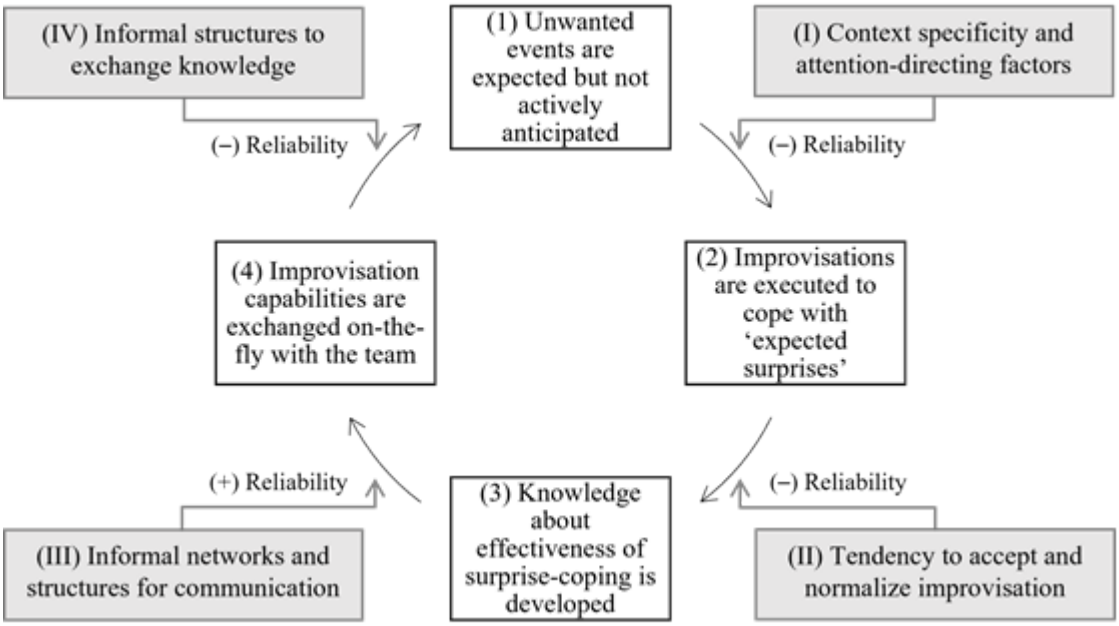


*Figure 1: Elements of reliability logic within the "improvisation enhancing cycle".*

These skills then reinforce the (1) recognition that the uncertain contexts of DH projects will always introduce 'expected surprises', leading to decisions to execute tasks using improvisation rather than based on planning and anticipation. The narratives from respondents are developed below to elaborate on the reliability of this cyclical process in detail.

### *(1) Unwanted events are expected but not actively anticipated*

Design and placement of DH systems demand scrutiny due to the inflexibility of their insulated pipes, which besides the specific requirements of welding operations, cannot easily be altered, or rerouted in the event of obstructions. Respondents explained that it is imperative to establish the pipe trace design well before construction stages and to anticipate buried obstacles. A foreman explained that a sophisticated design is needed to order the suitable pipe fittings for the conditions at the jobsite:

"If I have a pipe with a nominal diameter of 100 or larger, I cannot simply say we go half a meter down every 5 or 6 meters; I need to use fittings to bridge that height [difference]. And those [fittings] are not just readily available on site. Consequently, we must proactively examine the approach to address this matter."

Even other respondents recognised this need to scrutinise the project site upfront, they explained that their efforts to foresee unwanted surprises - such as unidentified buried objects - are usually

limited. Teams essentially anticipate all possible unwanted events only as part of: a mandatory cable and pipeline localisation activity (from the 'CROW500' directive); a desk study of written instructions for safe excavation from network operators (known as the 'Eis-Voorzorgsmaatregel'); and, the development of a basic health and safety plan. Usually, only on larger-scaled projects, these activities are executed in-depth. One respondent explains the depth of anticipation of unwanted events is mediated by the size of a project:

“In one large phase of the project, where the trace design is very complex, it contains many branches […and …] there are no [design] errors in its stretch of one kilometre. In the other [… smaller phase where…] the pipe diameters are reduced, there are fewer [complexities: only] T-pieces and directional changes. During [that part of the project, we encountered 3 or 4 errors, as we came across a tree; we could not place the pipeline at a suitable location under a street; and, we had to go around a manhole strangely. In my opinion, these mistakes truly resided in the extent to which the [planning of the smaller] subsection should have been considered more seriously.”

At its core, the reduced adherence to the mindfulness principle of resistance to simplification seems to have led to this avoidable but unwanted situation.

*(2) Improvisations are executed to cope with ‘expected surprises’*

The absence of adequate formal designs plans or measures to anticipate specific unwanted events engenders improvised project activities. This is reinforced by the unclarity of roles and responsibilities in the teams. For example, the scope that clients gave to project teams and the activities that a project team planned to execute were ill-defined, and not backed by defined structures or protocols. About this, one respondent argued:

“The disruption often occurs at the beginning of the process, where insufficient information is typically transmitted from the client to the engineers. This means that we receive an email, drawing, or sketch with the indication for a pipeline route together with the vague assignment stating: 'This is approximately what you need to engineer.' What we then do, is starting to work on [the design] first, and then, halfway through we re-think, 'what again were the tasks we were required to perform, and what agreements did we make?'”

This explanation shows that projects may commence with a vaguely specified scope and brief and that mid-project alterations to designs become necessary. Projects may start regardless of whether all the required documentation has been acquired from the client, creating uncertainties and hampering their sensitivity to operations.

Eventually, teams try to actively avoid all surprises. Unexpected technical changes such as the need to relocate existing other infrastructures around heating pipelines, and unexpected sanitation of polluted soil, then impede the intended construction plan. Similarly, activities induced by third parties, such as delayed confirmation of project contracts, and the late issuing of permits and deliveries of specialised materials create additional hiccups. Fundamentally, the project teams acknowledge the occurrence of these events and recognise the need to improvise as a response to the 'expected surprises'. This is shown in the following verbatim quote:

“In existing situations, you will always come across things [like existing utilities obstructing the DH pipeline route] that are not in the design. You can only deal with them when you encounter them. You can be lucky or not to be confronted with them. However, you cannot align a process with that [in advance], it is not possible.”

Essentially, project teams often seem to treat the available ill-defined documentation as the only 'facts available' for their project management activities. While they remain open to the possibility of unexpected events and changes, they are also overwhelmed by the many possible physical and procedural uncertainties that may unfold. Consequently, they decide not to anticipate all these events and simplify the project situation. This neglects possible risks and over-simplifies a complex project. This contradicts the principles of reluctance to simplification.

*(3) Knowledge about the effectiveness of surprise-coping is developed*

While improvising, respondents learn to take on unexpected challenges on the spot. This ability to contain unwanted events was based on their experiential knowledge. One foreman illustrated a project scenario in which his team acquired knowledge through hands-on experimentation and improvisation:

“We had materials available that were different from what was stated in the design. We had to be highly creative to eventually get the network built. It was designed to use T-pieces, but these were not available. So, we had to apply a slightly different method: tapping on the pipes. Ultimately, the construction work continued, and we had to compensate for the delay that this caused. We could not simply tell another contractor, that depended on us, to wait for another 6 weeks with the construction of houses because of our delay. That is not how it works in our work."

Such an ability to respond to such unexpected events was outlined by respondents more frequently. They seemed to have developed this by exploiting their interpersonal relations. Respondents said that unexpected events and the way they are dealt with are shared with others differently. Sometimes they are discussed within the project team organisation, and sometimes also with clients and third parties. Explicit learning based on feedback captured in, for example, structures, protocols, and best practices were, however not commonplace. The following explains that team members share their experiences and knowledge "on the job" and in more implicit ways:

“You can give someone a stack of books and a month to familiarise themselves with a company's procedures, but I believe that learning by doing is the most effective way. While certain things can be documented, most of what you learn is through hands-on experience, observation, and participation. I think that's the most crucial aspect in DH projects.”

On the one hand, this outlined activity of sharing knowledge supports the mindfulness principle of preoccupation with failure since it allows knowledge exchange about the avoidance of unwanted events spontaneously. On the other hand, however, it takes place on an individual level, and as a result, it limits explicit formal feedback in the form of reports or best practices made available to the wider team and beyond. Consequently, broader organisational development of preoccupation with failure is limited.

*(4) Improvisation capabilities are exchanged on-the-fly with the team*

Because the freshly established project team improvised and learned during previously executed DH projects, they became increasingly better at tackling the unwanted events that they expected. As one respondent explained, their collective experience was instrumental in their growth towards more reliable working:

“We already have so much experience and connections with other companies and colleagues. [In urgent cases] we [can] ask contacts on the other side of the country, ‘do you have [a spare of] this

fitting, do you have that fitting?'. And of course, we can [now] also make [network appurtenances] ourselves. That is where we are now."

Such examples of coping with supply disruptions through interpersonal networks show that issues are resolved but fail to reflect on the root causes of the disruption, which might trace back to previous design or engineering stages. Respondents argued that their strong hands-on mentality and ongoing time pressures disincentivise such a reflection, eventually limiting adherence to the principle of preoccupation with failure.

# DISCUSSION

This study describes and assesses the reliability coping processes of DH project team members. We found that teams work in a self-reinforcing cycle of activities and decisions that consists of four components (Figure 1, 1-4) and mediating conditions (Figure 1, I-IV). Altogether, these constitute a reliability logic that makes teams improvise better over time, while also leading to the normalisation of unwanted events and improvisational activities. These together create a logic within the team that discourages many formal planning and anticipation activities.

We found that the reliability logic in Figure 1 describes a process that deviates from the mindfulness principles in the reliability literature. Typically, organisations in the literature successfully apply these principles under stable operating conditions, where the system demonstrates a significant level of formalisation, standardisation, and hierarchy (Bigley & Roberts, 2001). Examples of this are aircraft carrier operations, nuclear power plants, healthcare teams, and wildland firefighting crews (Weick & Sutcliffe, 2007). The formal structures provide a necessary but minimal foundation for the implementation of highly reliable organising in both stable and 'unwanted' situations. Emerging project organisations, such as the district heating project organisations in this study may, however, not yet have such established structures.

We believe that the lack of foundations to organise 'normal modes' of operating may explain the existence of the improvisation-enhancing cycle in DH project teams. The many uncertainties arising from the physical project context, and the existence of stimuli that limit attention to only a few unwanted events, hamper a holistic perspective on reliability. Although project teams exploit informal networks and exchange experiences 'on-the-job' to troubleshoot successfully, these problem-solving approaches fail to embed gained knowledge more systematically.

Ultimately, DH professionals heavily rely on experience, intuition, and personal insights that they acquire through practice and observation rather than formal knowledge exchange. Such limited organisational transparency and the lack of receptivity to gained knowledge can ultimately become impediments to enhanced learning capacity (Child 2015, pp. 309-337). They also magnify the learning paradox in the CM literature, which explains that project-transcending learning is already difficult in our sector (Bakker et al., 2011).

Like any other study, this research also has its limitations. One limitation is that our explicated self-reinforcing cycle stems from narratives developed from twelve explorative interviews with professionals. We suggest extending this sample by repeating the interviews for similar organisations in other emerging contexts to further refine, validate, and generalise our findings.

Ultimately, this study also has practical implications. The lacking structures for 'normal modes' of organising on one hand, and the difficulties to increase learning capacity on the other, present a reliability challenge to DH network project organisations. Despite this challenge, more DH

construction teams need to be trained to accomplish zero-emission goals. We hence suggest that organisations can only scale up effectively if they recognise the significance of minimal accountability structures for members, and when they create foundations that can bring experiential knowledge beyond the individual and peer level. This professionalization may eventually increase reliability.

## CONCLUSION

The construction of DH systems involves the deployment of large, rigid insulated pipelines in crowded urban areas. While the demand for these projects will likely increase, the structures and work practices of its project organisations are still under development. To explore how the professionals in this practice try to organise reliably we conducted twelve semi-structured interviews with project members at a DH network specialist contractor. Based on narrative analysis and matching with the principles of reliability organising, we found a reliability logic based on a self-reinforcing cycle of activities and decisions. Here, improvisation is both an outcome and the main driving factor.

Findings confirm that emerging organisation types may not have the foundational structures yet to organise reliably - and consequently need to improvise. Figure 1 shows that DH project teams are caught in a vicious circle where they employ formal planning and anticipation activities sparingly, which leads to their adeptness in improvisation owing to frequent unwanted events. The cycle starts with acknowledging the impact of uncertainties on DH projects. The heightened proficiency in improvisation seems to result in the avoidance of deliberate anticipation activities, while eventually the teams' progress is impeded by the dearth of avenues to share knowledge and experience beyond the individual and the project.

While being based only on the study of professionals in one emerging organisation, we show that physical project conditions and uncertainties arising from third-party decisions may create an imbalance in a DH team's anticipation and containment activities. Being caught in a vicious circle, teams may dedicate themselves to improvisation and implicit learning, eventually hampering process improvement and the exchange of reliability knowledge. This creates a challenge for the new DH network teams, which are likely to be founded as soon as the demand for the new energy infrastructure grows further. Future research should therefore focus on refining our reliability logic and expand to other organising work in emerging project teams'.

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