Constraint-shattering practices and creative action in organizations

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Abstract

This study contributes insights on how actors cope with constraints in ill-structured problem solving situations, and what implications this coping has for creative action. To date, most research on constraint handling has treated constraints, regardless of their nature, origin, or role, as external factors that enable or hinder creativity. In contrast, we consider constraints to be inextricably intertwined with all creative action. We focus our study on one specific practice for constraint handling: namely, shattering. Empirical data were collected for 12 projects in two engineering consulting firms, and four shattering practices were identified: protesting, proposing, betraying, and sabotaging. We discuss their enactment in various parts of the problem space and their implications for the management of creative action in organizations.

Keywords

Constraints, shattering, practice, creativity

Introduction

Ill-structured problem solving (Newell, Shaw & Simon, 1962) in project organizations is characterized by a need to handle any kind of constraint. How constraints are handled can affect the search for successful and creative solutions. Theoretical and empirical researches articulate constraints as both enabling and restraining creative work (Negus & Pickering, 2004; Stokes, 2008; Joyce, 2009; Onarheim & Wiltschnig, 2010; Onarheim & Biskjaer, (in press)). Whereas some studies conclude that constraints in the work environment are detrimental to creativity (Salter & Gann, 2003; Hennessey & Amabile, 2010), others find that constraints are a prerequisite for (Dyer, Gregersen & Christensen, 2009; Joyce, 2009) or even lead to creative breakthroughs (Stokes, 2005), opening numerous research questions about how practitioners handle constraints.

Despite the widely known definitional issues in creativity research (e.g. Woodman, Sawyer & Griffin, 1993; Eysenck, 1994; Amabile, 1996; Csikszentmihalyi, 1999; Sternberg, 1999; Klausen, 2010), most studies on constraint handling define creativity in terms of the output of the creative act, rather than in terms of individuals' actions (Zhou & Shalley, 2008; Sternberg & Kaufman, 2010). As opposed to the concept of 'rational action' that is commonly used to explain management phenomena (see Tsoukas & Knudsen, 2007), 'creative action' is mainly confined to the generative part of the problem space, in which alternative solutions are produced. The realm of rational

action has been thought to encompass the work of defining the problem and finding a solution. In the present study, we challenge this view, arguing that such work can also involve creative action.

Creative problem solving entails handling constraints (Sternberg & Kaufman, 2010). This is an interesting phenomenon that has attracted many scholars (Lubart, 1994; Csikszentmihalyi, 1996; Chevalier & Ivory, 2003) who have produced evidence about numerous constraint-handling practices (Gero, 1990; Stokes, 2007; Onarheim, 2012; Onarheim & Biskjaer, (in press)), which practitioners draw upon when defining and exploring their own problem spaces (Newell & Simon, 1972; Robertson, Scarbrough & Swan, 2003). Such studies have generally treated constraints, regardless of their nature, origin, or role, as external factors that enable or hinder creativity (e.g. Stokes, 2007; Onarheim & Wiltschnig, 2010). Yet, the constraints remain excluded from the conceptualization of the creative act itself (Klausen, 2010; Sternberg & Kaufman, 2010). Moreover, the practical logic of constraint handling (Bourdieu, 1990; Schatzki, Savigny & Knorr-Cetina, 2001) remains either ill-conceived or out of the research scope. Furthermore, the question of how constraints are handled is often subordinated to how to optimize the creative performance of individual practitioners (e.g. Koberg & Bagnall, 2003; Michalko, 2006; Biskjaer, Onarheim & Wiltschnig, 2011) rather than of optimizing the creative performance of project teams (Joyce, 2009; Onarheim, 2012).

Notwithstanding their important contributions, these approaches may lead us to overlook the possibility of *viewing constraint handling as something inherent in creative action*. We risk ignoring the possible role of creative action in the non-generative parts of the problem space, and dismissing any creative action that does not connect directly with useful outputs. Constraint handling is thus reduced to a form of 'creativity maximization', and cases in which constraint handling originates creative action without being related to any preset creative goal might be neglected.

We propose to develop the study of constraint handling from within theories of action that view all human actions as inherently creative, such as the theory of action of American pragmatism (James, 1922; Peirce, 1932-58; Mead & Morris, 1938; Dewey, 1958). This theory provides a clear role for constraint handling in the definition of creative action. According to pragmatists, human action involves problem solving and develops creatively by shattering old constraints and reconstructing new ones (Joas, 1996). In this context, 'shattering' is defined as a disruption of the status quo. Pragmatists consider constraint shattering as a fundamental form of constraint handling and as a source of creative action. Thus, creativity can be understood by means of its connection to constraint handling. Stokes (2007) acknowledges this line of thought while proposing rejection (Gardner, 1993) and replacement (Boden, 1994) as two basic

forms of constraint handling. Yet, we do not know enough about how shattering is enacted by practitioners. Thus, we ask: *How do project teams shatter constraints in ill-structured problem-solving situations, and what implications does this finding have for the understanding of creative action in organizations?*

Our aim is to elucidate a specific set of constraint-handling practices that are most likely to be used, regardless of the goal of creative performance. In our opinion, this approach is important for extending the understanding of the scope of creative action beyond the generative part (e.g. Ball, Evans, Dennis and Ornerod, 1997; Stokes, 2005; Onarheim, 2012) to other parts of the problem space (i.e. problem definition and solution assessment phases). This understanding could provide practitioners with insights about how to manage creativity in the work of problem solving. We see our contribution as a small step towards developing a theory of constraint shattering in organizations.

Constraints and creative action

Constraint handling is commonly studied in connection with creative problem solving (e.g. Chevalier & Ivory, 2003; Onarheim, 2012; Stacey & Eckert, 2010; Stokes, 2007), with the creative output being seen as a goal of constraint handling. Recent literature reviews (Onarheim, 2012; Onarheim & Biskjaer, in press) find great variation in the definition of 'constraints,' ranging from generic typologies (e.g. Amabile, 1996; Elster,

2000; Stokes & Fisher, 2005; Lawson, 2006) to ad-hoc typologies that focus on domain-specific constraints (e.g. Gross, 1986; Gero, 1990; Goldratt, 1990; King & Majchrzak, 1996; Nuseibeh & Easterbrook, 2000; Darlington, 2002; Andrews, 2003; Chevalier & Ivory, 2003; Abuhamedeh & Csikszentmihalyi, 2004; Johnson, 2005; Lewandowski, 2007). In the creativity literature, ad-hoc conceptualizations tend to define constraints based on their effects on the creative endeavor (Amabile, 1982; Stokes, 2008; Sternberg & Kaufman, 2010). For our purposes, we define constraints as *limitations or restrictions for what can or cannot be done in the problem solving, and for what the final solution should fulfill* (Onarheim, 2012, p. 324), and acknowledge that many constraints may exist at any point in a project (Hull, Jackson & Dick, 2005).

Problem solving comprises activities that occur in a problem space (Newell & Simon, 1972). The problem space contains three parts, an initial state (the problem), a goal state (its solution), and a generative state, with constraints applying to each. Diverse strategies and rules are applied to move from the initial to the goal state (Stokes, 2007). In the early problem-solving phases, practitioners must define the goal state (Simon, 1973; Darke, 1979; Voss & Post, 1988), a challenge that entails *finding* constraints in the problem, *resolving* contradictory constraints (Stacey & Eckert, 2010), and *transforming* such constraints into descriptions of the envisaged solution path (Gero, 1990). Through these activities, the practitioner establishes an understanding of the

status quo of the problem and the need for a change to reach the goal state (Simon, 1978). The practitioner produces creative solutions in the generative part, facilitated by the shattering of constraints.

Some studies consider constraints to be external factors capable of influencing the creative production in the generative state *from the outside*. Constraints are presented as something that can direct and limit the search for solutions (Reitman, 1965; Stokes, 2007), focus the creative effort (e.g. Isaak & Just, 1995; Ward, Smith & Finke, 1999), promote idea generation (e.g. Finke, Ward & Smith, 1992; Amabile, Hadley & Kramer, 2002), or even lead to creative breakthroughs (Stokes, 2005). Other authors focus more explicitly on practitioners' handling of constraints during problem solving. It is this part of the literature that resonates most closely with our research question.

Some studies find that practitioners balance between *eliminating* constraints to open possibilities and *introducing* new constraints to secure control (Csikszentmihalyi, 1997; Amabile, 1998; Baer & Oldham, 2006; Joyce, 2009; Liikkanen, Bjorklund, Hämäläinen & Koskinen, 2009). Constraint elimination takes various forms, such as *black-boxing* constraints (i.e. accepting specific constraints as unchangeable, while focusing on more 'crucial' constraints); *temporarily removing* constraints (i.e. to search for potentially overlooked solutions); and *revising* constraints (i.e. to solve creative hindrances)

(Onarheim, 2012). New constraints can be introduced during the solution process by *self-imposition* (Onarheim, 2012), by *translating* constraints into different forms and exploring their implications (Stacey & Eckert, 2010), or simply by chance (Charnes & Cooper, 1959). These various strategies have been used throughout the literature (e.g. Simon, 1969; Johnson-Laird, 1988; Toye, 1993; Chi, 1997; Bonnardel, 2000; Jul, 2004; Simonton, 2004), providing evidence of how practitioners use constraints as tools to challenge and shatter the status quo.

In most of the above-mentioned studies, authors tend to view constraints as tools external to the domain of creative action; to consider constraint handling as a mechanism for maximizing creativity; to define the creative action as something that produces a novel and useful output; and to consider individuals rather than groups or practices in their analyses. We argue that these conceptualizations lead to several shortcomings regarding our understanding of the relationship between constraint shattering and creative action.

First, by viewing constraints as tools (Stokes, 2005), practitioners include constraint handling within the domain of problem solving, but conceptually outside the definition of creative action. They overlook the possibility that constraint handling may be something *inherent* in creative action, rather than an external factor. Practitioners might

think that they can *choose* whether or not to use constraint handling; instead, it could be that constraint shattering (as a form of constraint handling) is never optional in the performance of creative action. In this case, the practitioner must gain an understanding of *how constraint shattering can be used to manage creative action* and *to what degree constraint handling can be conceived as inherent in creative action*.

Second, existing research tends to present constraint handling as a form of 'creativity maximization'. In particular, the case in which constraint handling originates creative action without being related to any preset creative goal does not receive particular attention. Practitioners risk ignoring the possible role of creative action in the problem definition and solution assessment phases of the problem space, where there is no explicit goal of being creative. To reduce this risk, creative action (and constraint handling as one of its components) should be understood in cases where the problem space has or does not have a planned creative goal, as well as when such a creative goal emerges unexpectedly during any phase of problem solving.

Third, most of the creativity literature considers an action as creative only when it produces a *novel and useful output* (Kaufmann, 2004). A creative output is explicitly assumed to be desirable. Under this assumption, actions that are not explicitly or directly involved in the production of novel and useful outputs can be dismissed as not

creative or interesting. However, such an action could be just one necessary step towards a subsequent action that will eventually achieve a novel output, or simply change the status quo. When we miss this point, we reduce our chances to recognize, appreciate, and manage essential creative steps on our way towards the final novel and useful output. This definition of creative action has other drawbacks: it requires that the output of the (potentially creative) action be assessable, and it does not account for inter-actor differences in what is considered creative (Sternberg & Kaufmann, 2010).

Pursuing the goals of novelty and usefulness is not problematic *per se*, although it may entail the risk of confusing the goal with the act of achieving it. This confusion overshadows what we consider the fundamental creative endeavor, which is reacting to the constraint shattering (Hitt, 1975; Puccio & Cabra, 2010). The act of shattering constraints and the reaction the follows, which may or may not induce a change in the status quo, is what ought to be understood and managed. Once the reaction to the shattering is completed, the *new* status quo can be assessed for novelty, usefulness, or compliance with the goal criterion (Simon, 1978). Only then should our attention shift from the creative endeavor to the assessment of its result. The assessed result can be used to judge the effectiveness or impact of the creative endeavor (Amabile, 1988; Mumford & Gustafson, 1988), and to guide the development of creativity management practices.

Finally, most studies tend to neglect the group dimension, use the individual actor as unit of analysis, and aim to explain the effect of constraint handling on the final product, rather than the constraint handling practices as such. Without the use of practice as unit of analysis, the logic behind constraint-handling practices remains largely unexplored (Bourdieu, 1990; Schatzki, et al., 2001). We argue that most of these shortcomings can be addressed by defining creativity in terms of *constraint shattering*.

Creative action

According to pragmatist tradition (Peirce, 1932-58; Mead & Morris, 1938; Dewey, 1958), all human action is anchored in an unreflected belief in self-evident facts and successful habits. However, with the repeated shattering of this belief (Joas, 1996; Camic, 1997), the individual discontinues his/her habitual actions. As old constraints are shattered, the action space becomes malleable, and the individual becomes free to act upon it. To proceed, the individual must redefine and reconstruct his/her space of action, a process that pragmatists and we define as the 'creative act'.

In this theory of action, all constraint handling concerns the release of an individual's capacity for new action. Constraint shattering is the fundamental releasing mechanism in this process. In this construct, creativity is anchored in action and conceived as 'the liberation of the capacity' for new actions (Joas, 1996, p. 133). This liberation is not

confined to any part of the problem space. On the contrary, creativity (conceived as the possibility for shattering and reconstruction) is possible in the definition of the problem (initial state) and in the assessment of the solutions (goal state).

This process does not assume a logical progression from an agent's entry into a situation to his/her assessment of the appropriate action to take to the final enactment of those actions (e.g. shattering or reconstructing) (Dewey, 1917; Joas, 1996). Instead, all of these activities emerge during the course of action. Importantly, the agent's concrete action is derived from the his/her personal habits and routines (Bourdieu & Wacquant, 1992). Shattering actions do not need to be rationally premeditated or targeted; rather, they are the unpredictable results of unique, personal, and situational settings. Such actions may be enacted in situations without a predetermined creative goal or even a clear goal for the action. Thus, it can be challenging to grasp the logic behind shattering actions or to explain them in rational terms.

Therefore, to understand creative action, it could be useful to acknowledge the ambiguous logic (Bourdieu, 1990) of these unpredictable shattering practices and to approach them 'as they happen' (Schatzki, 2006; Simpson, 2009) in real life, from the perspective of the problem-solving situations in which they are entwined. For this approach, we can use the theoretical (Bourdieu, 1990; Schatzki, et al., 2001; Chia &

Holt, 2008; Simpson, 2009) and empirical tools (Sandberg & Tsoukas, 2011) that practice theories offer. We propose that viewing constraint shattering as a potential source of creative action may provide a new theoretical lens for creative work in organizations.

Methodological approach

In this paper, we apply a multiple case design that allows for contrast, replication, and extension, with each case confirming or not the inferences drawn from the others (Yin, 2003; Eisenhardt & Graebner, 2007). The aim of the empirical study is to contribute to theory development on the relationship between constraints and creative action, with particular focus on the identification of different types of shattering practices (Bourdieu, 1990), which emerge when project teams face constraints in solving ill-structured problems, and how this relationship leads to creative action. We ground the theorizing in the empirical data (Eisenhardt & Graebner, 2007; Corbin & Strauss, 2008) and seek to gain an in-depth understanding of the research question, even at the cost of simplicity and generality (Langley, 1999).

Our unit of analysis is the situated practices that project teams draw upon when coping with constraints during problem solving in workshops. The level of analysis is the shattering practices that practitioners apply when coping with constraints in solving ill-structured problems. These choices are due to our need to grasp the logic of shattering practices (Sandberg & Tsoukas, 2011). We consider human beings as always already inextricably entwined with others and things in specific sociomaterial practices, including problem-solving practices (Schatzki, 2005). We define practice as *a routinized type of behavior, which consists of several elements, interconnected to one another: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, and states of emotion* (Reckwitz, 2002, p. 249).

Case selection

The research setting is engineering consulting firms. We conducted a theoretical sampling, looking for cases that could offer theoretical insight on the relationship between constraint shattering and creative action (Eisenhardt & Graebner, 2007). Hence, we looked for extreme examples of constraint shattering and its implications for creative action. Engineering consulting firms were used for this purpose because:

1. They often face ill-structured problems that may call for creative solutions.

2. They serve their clients within the framework of projects, where teams typically engage in problem-solving sessions. Clients are frequently invited to participate in these sessions, where problem-solving practices are observable.
3. In engineering projects, the constraints are particularly evident through project schedules, budgets, team design, contracts, and client specifications. We expect the phenomenon of coping with constraints to be particularly transparent in these settings.
4. Problem solving may be undertaken by single individuals, in small meetings or, as in larger multidisciplinary engineering projects, in workshops. Workshops are particularly interesting episodes in which organizational creativity emerges through actors' practices in the specific context of problem solving. Workshops may provide episodes of problem solving undertaken by single individuals or smaller subgroups. The literature provides useful conceptual frameworks for approaching workshops (Bettencourt, Ostrom, Brown & Roundtree, 2002; Hendry & Seidl, 2003; Payne, Storbacka & Frow, 2008; Johnson, Prashantham, Floyd & Bourque, 2010). Stabell and Fjeldstad's (1998) 'value shop' is a particularly useful framework for addressing professional service projects. The value shop has phases of problem definition, problem solution, choice, and execution. All of

> these phases are likely to have variations in terms of which constraints may apply and opportunities for the actors to handle these constraints and act creatively.

We had access to two engineering consulting firms that had several ongoing projects facing ill-structured problems. Good access is important when selecting cases for developing theoretical insight (Eisenhardt & Graebner, 2007). These firms were particularly convenient because the first author was granted privileged, long-term access to all project and strategic information at the middle- and top-management levels in both firms. We met project members while they engaged in intensive collaboration, and we observed problem-solving practices in formal (group work) and informal (breaks) sessions.

We further reduced the number of cases to 64, by selecting those for which we had access to secondary data, which provided background information on the projects in the strategic context of the firm. These projects were led by 18 managers who volunteered to have a deeper and longer informant-researcher dialogue throughout the various phases of their projects. It was important to have access to these people, because they represent what Eisenhardt and Graebner (2007, p. 28) call *highly knowledgeable informants who can view the focal phenomena from diverse perspectives*.

Next, we divided the 64 projects into three subgroups, aiming to study shattering practices both when creativity was an explicit goal and when it was not. The first subgroup was chosen to maximize transparency (Pettigrew, 1990) and insight (Eisenhardt, 1989) into the problem-solving practices in cases that had a formal goal explicitly requiring a creative output. These cases represented an empirical setting of the traditional view on the relationship between creativity and constraints (Stokes, 2005; Dyer et al., 2009; Joyce, 2009). Project managers (PMs) considered these projects to be of such importance for the firms and the clients that executives were expected to attend the workshops, and the interactions with clients were expected to be intense. Actors involved in these projects were expected to struggle with constraints in order to deliver the required outputs. Four projects qualified in this first subgroup.

To ensure polarity and contrast in our data, we selected four cases defined by PMs as having opposite characteristics to the first subgroup (e.g. no formal expectations of creative output, low client interaction intensity, low importance of the project for both parties, and no executives attending the workshops). In accordance with existing theory on constraints and creativity, not much of creativity (i.e. creative output) was expected in such cases (Amabile, 1998).

After analyzing these cases, we acknowledged that, in the real world, most cases would fall between these two ends of the creative goal continuum. Therefore, we selected a third group of four cases that was classified between these two extreme groups. The aim was to control for the first bulk of findings and search for the same practices in cases where the creative goal was not explicitly in focus, but was welcome.

Insert Table 1 about here

The validity of the case categorization in the three groups was confirmed later, by examining the content and results of each workshop in the context of the larger project that it was a part of, and with respect to, the strategy of the current business unit (BU).

Data sources and collection

Empirical material for this study was derived from multiple case studies conducted in real-time, from August 2009 to the end of April 2012. We collected data from several sources. Primary data included participant and non-participant observations in all workshops, preparatory meetings at the firm, and follow-up meetings, wherein we

followed the suggestions of Sandberg and Tsoukas (2011) and sought for temporary breakdowns that could unveil elements of the logic of the actor's sociomaterial practices. Other primary data included two to four interviews per case, to add data from actors' post-hoc rationalizations of their own practices, informal conversations with workshop participants, as well as oral and written self-reports from 12 project managers who volunteered for that purpose. Secondary data included background information for the projects, workshop minutes, and the drafts and final versions of the workshop deliverables.

To track preparations, data collection began 1 to 3 weeks before each workshop started. This time frame was necessary to record as much data as possible about project constraints in the problem-definition phase. Data collection continued up to 12 months after the workshop ended, to gather data about the workshops' consequences for the project. Each workshop lasted up to 2 days. All discussions and interactions that occurred during the workshop phases, including preparatory and follow-up meetings, were directly observed by the first author (as a non-participant), who also attended informal meetings among the participants in each of the engineering consultancy firms. With few exceptions, neither the workshops nor the preparatory and follow-up meetings were tape-recorded because of the confidential nature of the content (Laurilla, 1997). Therefore, during the workshop, extensive notes were taken, including verbatim quotes

and notes on expressions and body language, to register informal and non-verbal communication. The first author wrote up these observations within 24 hours (Yin, 2003).

In addition to field notes, the first author used frequent informal on-site interactions with workshop participants to obtain secondary background data about cultural settings, biographical background of key workshop participants, and previous experiences with creative processes. Two weeks after the workshop, the first author interviewed one or two key persons from among the clients and from the consultant organizations to query the content, processes, and outcomes of the workshop. This step was done to examine the importance of the workshops from the clients' and consultants' perspectives.

To achieve triangulation in our analysis, secondary data were also gathered from written corporate databases (i.e. project documentation, emails, meeting minutes, and strategy reports) to get a flavor of the recent history of the BUs and a picture of the most evident constraints (budget, schedule, scope, mission, etc.) imposed on each project organization.

Data analysis

Our analysis of the 12 selected cases focused on the relational whole in data concerning practitioners, activities, and tools (Sandberg & Tsoukas, 2011). We looked for patterns and recurring shattering practices that emerged as a consequence of constraints in the projects, and we explored their influence on the creative action taking place (Yin, 2003; Eisenhardt & Graebner, 2007). Because this was a multiple-case study, we conducted both within- and between-case analyses (Eisenhardt, 1989). We performed data analysis through five cumulative phases (Corbin & Strauss, 2008; Jarzabkowski & Seidl, 2008) starting with the within-case analysis of each case.

First, we identified and categorized the entire workshop data set. Each case comprised several basic primary data items, which we categorized using our operational definition of practice (from Reckwitz, 2002), as shown in Table 2.

Insert Table 2 about here

These data provided the components that we used to create narrative accounts of the workshop events and detailed narrative descriptions of the work practices used by the participants.

Second, we placed the case data from the workshops into a broader project and organizational context, by triangulating our field observations and interviews with secondary data (e.g. project plans, contracts, BU strategy documents, emails between BU management and clients, personal CVs, and, where available, memoranda from earlier workshops held on the same projects) (Jick, 1979). These data were used to describe, in narrative form, the firm-level (i.e. current strategy, service delivery process descriptions, project references, etc.) and project-level (i.e. contract, budget, project team, project plan, deliverables, etc.) contexts in which each workshop was embedded (Pettigrew, 1990; Langley, 1999). The project context was further described as an overview of project tasks performed during the three project phases (problem definition, problem solution, and choice of preferred solution) (Stabell & Fjeldstad, 1998). Through these overviews, we identified which phases were covered by the workshop and by the preparation and follow-up meetings that we had observed in real time.

Third, we developed the analytical approach for the projects' narratives in terms of the definition and categorization of the projects' constraints. We reviewed the primary and secondary data to understand which project issues could be considered as objective / factual constraints. This category would contain project data (e.g. budgets, schedules,

contractual issues, and scope descriptions) and written / audiovisual recordings (e.g. newspaper articles, project owner interviews in the mass media, and similar data).

We analyzed the primary data (interviews and field notes) to discover what workshop participants and project team members considered as constraints, based on their subjective perception of the issue at hand. This analytical step was crucial for categorizing the observed shattering practices. In our primary data, we found variation in how openly people lamented the presence of constraints. This crucial aspect gave us insights into *how constraints were understood and acknowledged* and *the level of tension that the constraint provoked* in the group or subgroup. Supported by recent studies on the relationship between creativity and different levels of constraints (Amabile, 1998; Baer and Oldham, 2006; Liikkanen et al., 2009), we considered whether this tension level could be related to the outburst of shattering practices, and whether these practices could mirror the actors' levels of openness. Accordingly, we categorized the same primary data by their 'level of openness' (Table 3).

Insert Table 3 about here

In Table 3, we use the term ‘formally’ to mean that participants (singles or groups) lamented potential problems or risks caused by constraints, and they formally (i.e. strongly) requested the PM’s attention to consequences for contractual issues (e.g. project schedule, deliverables, payments, and client-professional relations).

These two analytical steps yielded a list of issues that were considered as constraints by the participants. Next, we used the reviewed literature (e.g. Onarheim, 2012; Stacey & Eckert, 2010) to cluster these constraints ad-hoc into the following four categories:

- Political constraints (e.g. defined vision, mission, scope of the projects);
- Technical constraints (e.g. access to competences or technologies; natural conditions, such as geology, landscape, and climate; existing infrastructures);
- Social constraints (e.g. codes of conduct, organizational hierarchies, personal relationships, accepted / expected behaviors); and
- Administrative constraints (e.g. budget, schedule, other written contractual agreements).

Fourth, to discover which constraints had been subjected to shattering practices, within the narrative accounts of each workshop case, we matched descriptions of the

constraints with those of the work practices (see Table 2). This analysis revealed that some work practices were related to challenging and disrupting constraints. Focusing on one case at a time, we sought those action patterns that constituted shattering practices and the specific categories of constraints that actors addressed through them.

We then performed between-case comparisons, focusing on replication and contrast (Eisenhardt & Graebner, 2007) and searching for variations in the types of constraints addressed and the patterns of actions that constituted these shattering practices. We looked for cross-case regularities and common patterns of shattering practices.

Based on the observed patterns and recurring themes, we determined that the reactions to constraints addressed the constraint directly or indirectly, the latter targeting only the (feared) consequences of the constraint. Although this fear could be considered as another form of constraint, we appreciated its idiosyncratic manner of unleashing shattering practices. Therefore, we defined ‘directedness’ as a second fundamental dimension to describe those practices that practitioners enact when they can live with a constraint, but not with its consequences.

Finally, we interacted between the theory and the data to clarify the findings and the theoretical arguments. Due to space restrictions, we focus on empirical evidences from three cases that offered high transparency of the phenomenon under study.

Shattering constraints in real life – three stories

In the following sections, we provide extracts from three of the case narratives, which illustrate how constraints and shattering practices took form and mutually influenced each other in our cases. In the narratives, the code Cx.y is used to identify constraints (see Table 4), and the code Px.y (see Table 5) is used to identify observed shattering practices (x = case; y = item #).

Case 1: Upgrading manufacturing machinery (formal creative output expected)

The Managing Director (MD) of a copper tube production plant in North America discovered that a set of recently upgraded cut-to-length (CTL) machines performed poorly, showing consistently low reliability and low operational stability. Several CTL machines had to be upgraded, and the MD could not afford to face similar problems for these machines. Therefore, an improvement project was established, and the project was

kicked off with the invitation of a team of specialists (two external consultants and six plant managers) to a problem-solving workshop.

The scope of the project and purpose of the kick-off workshop were set by the MD alone and communicated on the first day of the workshop through the following statement: *Achieve a sustainable Overall Equipment Effectiveness* (O.E.E.)[1] *of 85% for all recently upgraded CTL machines within 2 months*. By setting this workshop goal, the MD imposed constraints on the technical (e.g. O.E.E. definition, C1.2, and O.E.E. degree to be achieved, C1.1), economic (e.g. investment level needed, C1.4), and administrative (e.g. action plan and deadlines to achieve the O.E.E. goal, C1.5) scopes of the improvement project. Some of these constraints (e.g. the budget available for upgrading the CTL machines, C1.5; availability of key experts to lead the CTL upgrade operations, C1.6; acceptable downtime per machine; and complexity of the human factor in plant operations) were explicitly mentioned in initial discussions among workshop participants. The group appeared to accept the constraints and welcomed the challenge.

At the start of the workshop, the manufacturing and maintenance managers (herein, M&M managers) openly and unexpectedly protested against the technical constraints

[1] O.E.E. is a measure of the current production efficiency for a machine.

imposed by the MD (P1.1). They contested the lack of validity of the O.E.E. definition, stating: *This definition is too academic and does not take into account the real metrics and measurements that we use in our daily operations*. Despite the calm tone, this protest was shocking because it aggressively questioned the MD's technical knowledge of the plant's daily operations. The M&M managers proposed an alternative O.E.E. definition, based on the technical figures that they normally used (i.e. as a function of the amount of downtime suffered and the scrap volume). Participants accepted this change and indirectly planned to exclude from the problem definition any technical aspects other than those that were already in use in daily operations.

Animated by the success of their first protest, the two managers added that the given goal of 85% O.E.E. was far too high (P1.2), and that they could accept *to aim for no more than a 70% O.E.E*, simply arguing that this would be *the only realistic goal for the plant*. Furthermore, they protested against the deadline proposed by the MD (P1.3): *Stability in real operations means to run at a stable O.E.E. level for 8 weeks. This alone is 2 months. But first, we have to get there… We need at least 4 more months.* Despite the clear allusions to the MD's lack of knowledge and the clear refusal of his legitimate ambitions for the plant, the MD did not publicly oppose this scope revision. The final version of the workshop goal was set *To achieve a sustainable O.E.E. of 70% in recently upgraded CTL machines within 6 months*. In less than 20 min, the protest had

effectively managed to reshape the technical and administrative constraints imposed on the project. Indirectly, these changes in technical constraints contributed to mold new constraints to the project's economy (i.e. investment needs had to be recalculated, C1.4) and organization (i.e. decreased need for consulting services, C1.6, and longer project schedule, C1.5).

Although the tone of the conversation was calm, as the workshop abandoned the problem definition phase and entered the problem solution phase, the group was facing an attack against the hierarchy and a mounting, yet hidden, interpersonal conflict. In a follow-up interview, a consultant revealed that: *The managers of manufacturing and maintenance thought that they were already handling the problem sufficiently well in their daily operations. They considered having such a workshop as a statement of the inefficiency of their work*. In fact, they had participated in the workshop to work against any idea that they challenged the status quo. This 'tension in the air', as one informant put it, created an additional, not openly acknowledged, constraint (C1.7) to the problem-solving activities.

The formal setting of the workshop's problem solution phase was a creative session. With the new constraints negotiated and (apparently) accepted by the whole group (two consultants, MD, and managers for manufacturing, maintenance, logistics, sales, human

resources [HR], and operations), the formal expectation in this phase was to perform some out-of-the-box thinking. However, as the HR manager stated, *It was not really safe to come up with ideas. Really creative ideas would hurt those who had their reputations attached to the status quo, while trivial ideas would deceive the leadership*. The mismatch between the MD's expectations and the M&M managers' hidden agenda made most participants act defensively during this phase.

As ideas started to flow, the M&M managers sabotaged the creative effort by basically re-proposing what already was being done (P1.4), forcing the group into longer discussions about the status quo. Towards the end of the problem solution phase, the operations manager reacted to this mainstream thinking. Having joined the workshop 2 hours later than the others, he pointed out that, despite the many proposals recorded, the group was missing the real problem. He protested that the measurements used by the M&M managers gave only a partial picture of the reality on the shop floor, one that was insufficient to understand the problem (P1.5). According to him, much of the problem was related to what he defined as 'the human side': the know-how, concentration, and motivation of the machine operators. None of these aspects were being assessed by any of the O.E.E. models mentioned by the other managers. Nobody was able to argue with the operations manager's statement, which further fueled tensions among participants (C1.7). External consultants reacted by proposing some ideas related to enhancing the

know-how and motivation of the machine operators, but these ideas were isolated in the total volume of proposals produced until then.

The solution choice phase was performed the next day, with the group generating a set of assessment criteria for the proposals. The operations manager was absent during this task, and the final set of assessment criteria did not account for his views (i.e. operator-related problems as a key issue in the solution). The structure of the final idea assessment task inherited the constraints that had characterized the creative phase of the problem-solving process. The arguments of the initial unexpected protest, which had produced a mass of mainstream ideas, were now formalized in a set of assessment criteria. The managers, who feared the consequences of a too-high O.E.E. goal (C1.1.), finalized their shattering of that constraint by openly using their own criteria to confirm their initial statements through the formal assessment of ideas (P1.6). Given that the data to be assessed only partly mirrored the key issues to be solved, the possibility of achieving novel solutions through the choice phase was limited. The winning ideas turned out to be well-known and currently ongoing activities.

In a follow-up interview, a participant commented:

> *Despite the tidiness of the problem-solving process, the interpersonal tension* (C1.7) *experienced during the workshop contributed to cast doubt on the real*

quality of the ideas produced and on the validity of their final ranking. What would the final ranking look like if we used the criteria proposed by the operation manager?

Case 2: Designing a new highway (creative output not required, yet welcomed)

In 2011, the Public Road Administration (PRA) of a Western European country launched a project to upgrade a 20-km-long highway segment in a high-traffic area (C2.1). Two years earlier, a re-engineering solution had been designed for that highway segment (C2.2), and the proposal was approved by the local authorities (LAs) through hard political negotiations (C2.3). The PRA issued a public tender to review and further develop the existing solution (P2.1), to achieve higher traffic safety standards, lower building and maintenance costs, and leaner administration of the construction process. At the start of the project, it soon became clear to the consultant that the reviewed and improved solution had to be consistent with a previously proposed and accepted one (C2.2). Substantial changes would require a new time-consuming political acceptance process (C2.3), which would jeopardize the PRA project's deadlines and budget, forcing the project management at the PRA to do what it wanted least: enter new negotiations with the LAs.

Consultants were tasked with the challenge of delivering better, cheaper, and politically acceptable technical solutions, while avoiding changes in the project budget and schedule. Their project work was organized through a series of problem-solving workshops, including creative sessions followed by 'idea assessment' sessions. To meet the PRA's requirements, engineering efforts had to focus on redesigning expensive constructions (e.g. tunnels, bridges, water piping, etc.) and reviewing the horizontal and vertical highway plan, including the junction design.

These necessities were problematic; as a senior consultant stated during a work group conversation, *If these guys* (the PRA) *really want to save money, we must shorten bridges and tunnels.* One of his colleagues added: *This might mean radical changes in the highway line,* inducing the PRA representative in the group to ask: *But wouldn't that also mean a new round with political acceptance?* It probably would. This conversation was emblematic of the dramatic developments that the project was about to experience. Cheaper construction and higher traffic safety would force the PRA to bring the new highway design back to the LAs for a new acceptance procedure. *The project would be further delayed, and we would again get the media on our backs,* the PRA senior engineer concluded.

At the start of the first creative session, participants (divided into five work groups, A–E) were presented with the given constraints (C2.1, C2.2), before engaging with the re-engineering tasks.

Participants in group A seemingly accepted the given constraints and focused on working around them, proposing solutions that would not be subject to assessment by the LAs (P2.2). A PRA engineer in group A proposed: *For this junction, we could use the same design* (i.e. same dimensions, no additional area needed), *yet we could move it a 200 m south to flatter terrain, to reduce the volumes of disposed mass* (a cost reduction). A consultant in the same group proposed: (moving) *the highway line away from the local tannery, at profile 4850, to avoid the land acquisition costs that that would cause.* Other proposals from the same group included minor horizontal and vertical movements of the main line to optimize mass balance (i.e. to reduce construction costs) and redesigning the system of adjacent local roads subordinate to the new highway (i.e. to enhance traffic safety related to entering or exiting the highway).

Another proposal was ‘to adopt an LED-based lighting system at the major junctions’ (to reduce energy costs)’. This proposal was innovative, as no LED technology had been used until then, and the cost reduction was realistic. It was politically wise as well, because no permission from LAs was necessary to implement the technology (C2.3).

Constraints were being worked around, new solutions were being sought and proposed, yet no real innovation in design was achieved. No substantial cost savings were made possible.

Group D, composed of three senior consultants and two PRA engineers, adopted a different practice. They did not openly protest against the constraints imposed by the PRA's project management. They targeted the design of tunnels and bridges (potentially controversial ideas), aiming for larger savings (P2.3). Some ideas concentrated on how to shorten tunnels, for example: *Moving the highway 50 m toward north at profile 5300, we can place the portal on the northern side of the hill and shorten the tunnel by several hundred meters* (up to 3.7M€ savings). Others focused on how to avoid tunnels entirely, for example: *We can avoid this tunnel if we lift the highway line and provide an alternative set of fauna passages beneath the highway* (up to 5M€ savings).

They also tried to identify all of the bridges that could be eliminated, changing the vertical profile of the highway, for example: *This bridge at profile 3100 can be substituted by a culvert if we lower the highway 15 m between these two profiles* (up to 1.8M€ savings). For those bridges that could not be eliminated, the group produced alternative designs of the highway sections that allowed for shorter bridge lengths, for example: *Lowering the line between profiles 900 and 2500, we can shorten by more*

than half the length of this bridge (up to 3.8M€ savings) and *Shorten the bridge between profiles 4250 and 4350* (up to 3.1M€ savings). All of these ideas were accompanied by drawings and sketches (P2.3).

Another group (B), after having produced a few politically wise ideas, engaged in a particularly creative design of one of the most important junctions in the highway segment (P2.4). This new design was much more functional and traffic-safe than the previous one. It presented a larger junction than the original, and it potentially forced the PRA into some difficult and unplanned land expropriations.

Generated ideas were recorded by the groups in writings and drawings and were formally delivered to the PRA's project management just before the idea assessment phase. This phase was essential for analyzing the proposals to enable the project owner (PO) to choose the best solution(s). This phase was run by one, much smaller, group that included the PO, the consultant's PM, and two senior engineers, one from each side. Interestingly, when assessing the ideas, the group placed more importance (i.e. higher weight) on *potential cost savings* than on criteria such as *political risk* (P2.5). Ideas that ignored given constraints summed up to about 12M€ of potential savings, compared to 2M€ obtained from those ideas that were designed to avoid a new round of political negotiations on the new highway design.

At the end of the assessment phase, the PRA's management had an overall satisfying design from the perspective of traffic safety standards, with potential savings of >11% of the original budget (~14 M€ from a budget of 124 M€). PRA managers began to consider adjusting the project schedule, presenting the new project design to the LAs, and initiating new political negotiations. The new design was eventually accepted (P2.3), but the original schedule was delayed by 6 months.

Case 3: Strategic high-speed railway planning (creative output not expected)

A large engineering consulting firm (herein, the firm) was hired by the National Railway Authority (NRA; herein, the client) to develop part of the national strategy for the development of a high-speed railway (HSR) infrastructure (C3.1). This project was of particular strategic importance to the NRA. The country does not have HSRs, and this kind of strategic infrastructure planning could influence railway development throughout the country for decades to come.

Two main constraints conditioned this project, as explained by the PO:

> *High-speed trains have to reach their top speed quickly and keep that speed as long as possible on their way to the destination. The number of stops has to be minimized* (C3.1). *In this country, this is a problem because the potential passengers are distributed in small towns scattered across large regions* (C3.2). *While InterCity (IC) trains serve most small towns to secure adequate passenger volumes, high-speed trains just cannot stop to pick up small volumes of passengers in small towns. Secondly, while IC railways can follow the landscape and adjust their lines to local environmental, historical, and private industrial interests, HSRs require much straighter lines, and must cut through any kind of landscape and any kind of local interests in the name of high-speed* (C3.3).

Acting on these facts would create conflicts with local administrations and populations who would see their local interests sidelined, in order to build railway lines that would not even offer a local station (C3.4). The NRA was facing a dilemma. As a senior NRA engineer put it: *The choice is, seemingly, between empty high-speed trains and full but slow IC trains*. For this reason, the PO at NRA played down the creative ambitions and formally asked consultants to consider three specific approaches:

A. To propose totally new HSR tracks separated from the existing railway network;

B. To upgrade, as much as possible, the existing IC network to high-speed standards (C3.3); and
C. To reconsider and further develop the existing IC strategy (no high-speed).

Approach A would assume aggressive infrastructure planning, cutting through landscapes, preferring speed to any other kind of concern, and heading into political unrest and environmental activist protests. Approach B would be a moderate upgrade of the existing infrastructure. Approach C would not require any high-speed planning. The client requested that all approaches be explored.

The firm's PM started the work by organizing an engineering workshop to be conducted in the early phase of this project, with representatives from the firm and the NRA. The firm's PMs and the NRA agreed that the workshop had to produce alternative solutions within approaches A, B, and C, as proposed by the NRA, focusing on one approach at a time (C3.5). The problem was ill-structured; although the technical constraints for this job were clearly presented, the administrative and political ones were not. As senior engineers commented: *the mission could not be more unclear* and *approaches B and C mean renouncing a true high-speed train policy in the country* and *there is no need for the C approach… do they want HSRs or not?*

During a preparation meeting at the firm, which took place the day before the workshop, a few senior engineers decided to ignore the agreements, protesting that working on approach C (C3.5) would take precious time away from high-speed planning. One of them invited the PM to introduce a preliminary session:

> …*to create conceptual high-speed solutions at higher conceptual level* (i.e. long, straight railway lines through large regions, with no attention to technical details such as curvatures, local geology, existing railway tracks, etc.), *without taking into consideration the constraints given by the B or C approaches. We want to create real high-speed concepts, before going into details* (P3.1).

To force this kind of thinking, he wanted to add a new formal session at the start of the workshop and provide participants with: …*topographic maps providing an overview of the region. Much larger maps than those normally used to plan railway corridors*. These concepts were to be developed regardless of the guidelines issued by the authorities (P3.2). The reason he provided was: …*to allow real creative thinking on high-speed. Playing by the rules will not bring us anywhere here. We will be caught up in traditional IC planning. There is no excitement*.

Thus, at the start of the workshop, instead of drawing approaches for A, B, and C, the groups were asked to free their thinking completely and produce a minimum of eight high-level conceptual solutions each (P3.2). Given two cities to be connected by HSR, they had to draw alternative HSR lines throughout the region. Next, participants were asked to choose four of these generic high-level concepts and make them more specific, using a more-detailed topographic map, explicating how the railway line would actually pass through the landscape of smaller towns, hills, lakes, etc. The solutions to approach A were created in this way, and the entire workshop was spent on that approach only (P3.3).

The formal intention at the workshop was to spend time on approaches B and C as well. However, the change introduced the day before (P3.1, P3.2) by the two senior engineers effectively sabotaged the workshop and conceded no time for the groups to work on alternatives other than the pure high-speed ones. This small group of consultants had managed to steer the work out of the given boundaries and in the direction that they, alone, considered to be the most reasonable one for the project and for their client. This decision to sabotage the original agenda and ignore the given planning policy was experienced by the NRA as ‘a clear breach of the agreed plan for the workshop’ (C3.5) and, even worse, as ‘an implicit, unjustified, and somehow aggressive statement of the inadequacy of (the clients’) planning process (C3.1)’.

Through this initial phase, several ideas came up that were well within the constraints (much like traditional IC lines). Still, many ideas (i.e. four to five out of eight in each group) presented clearly novel high-speed features, which encouraged the whole group to pursue uncompromised HSR thinking. This practice allowed the participants, both clients and consultants, to think outside the given constraints. The tension created by the sabotage was tempered by the workshop's output: participants produced many concrete and novel solutions for uncompromised HSR lines (approach A). To perform idea assessment, criteria were used that favored high-speed solutions (P3.4). To moderate the effects of shattering the project goals (C3.1), high-speed ideas that were characterized by traditional IC features were assessed as innovative approach B solutions.

From constraints to shattering practices

The project teams in this study were faced with different types of constraints, as summarized in Table 4.

Insert Table 4 about here

A few patterns emerged as we compared the data on how practitioners in the three cases enacted their shattering practices to address some of the constraints. Table 5 presents a detailed overview of this comparative analysis.

Insert Table 5 about here

Shattering practices in problem solving

Some of the shattering practices were characterized by patterns of confrontational actions (e.g. P1.1, P1.2), which generally were used to question the project team's willingness to accept the given project constraints (e.g. P3.1, P2.1). The actors *protested* loudly against the given constraint, openly questioned its validity, and prompted the rest of the group to support them. These shattering practices were found during the problem definition phase. They were highly destabilizing and effective in opening new possible problem definitions. *Protesting* was very effective in terms of eliciting reactions, further energizing the group's interactions, as well as fueling conflicts and stressful situations within the groups.

A second group of shattering practices was represented by actors who, after becoming aware of the constraints, limited themselves to working around them through a recurring two-step procedure. The group initially accepted the validity of a given constraint, and then timidly assaulted it during the generative phase, by proposing a series of alternative solutions to work around the constraint (see P2.2), or during the assessment phase, by proposing a set of assessment criteria that dismissed the constraint altogether (P1.6 and P3.4). *Proposing* is the key action here. Unexpected and challenging proposals elicited creative reactions and encouraged other participants to work around the constraint. Shattering the constraint in the assessment phase produced a completely different setting for the choice of the preferred solution than the one planned during the problem definition phase.

A third pattern of very disruptive practices had as its peculiar characteristic an unrestrained production of ‘illegal’ solutions. These solutions were generated by subgroups who, like in the proposing pattern, did not publicly express any discontent regarding the given constraints (see P2.3 and P3.3). The actors did not protest against the constraint, but they did not accept it either. They challenged only the consequences of it, by working silently on only ‘illegal’ ideas. We call this group *betraying* practices, because the actors consistently and explicitly worked against the boundary conditions

that the whole project team had, apparently, agreed upon. Other workshop participants discovered the results of these disruptive ideas only after they were officially recorded among the workshop deliverables, or even later during the solution assessment phase.

A fourth group of practices used in the problem definition and generative phases had a notable rebellious nature. These actors worked secretly against the unwanted consequences of a given constraint. They conspired to achieve a different definition of the project's purposes and set up, but never engaged in public interactions that could unveil their intentions. There were neither overt protests nor smart proposals to work around the constraint, nor any consistently 'illegal' propositions. Instead, the actors engaged in a kind of *sabotage*, changing the rules of the game (see P3.2) and imposing their own agendas (see P1.4 and P3.2).

Once we became aware of the constraint addressed, these patterns could be easily observed, as the solutions produced were almost disjointed from the project's original scope.

Discover and understand shattering to manage it

In all parts of the problem space, shattering momentarily released the project teams from their constraints and provided them with opportunities for creative reactions. On some occasions, the teams recognized and seized these opportunities, managing various forms of creative reactions (see P2.3), even when the project was not aimed at creative solutions (P3.2, P3.3). On other occasions, they did not recognize and act on the opportunities for creativity (see P1.6 and P3.4). In these cases, constraint shattering was insufficient for creative action to blossom, and no reaction followed the shattering. Shattering the project goal by adopting assessment criteria that promoted ideas against it (see P1.6 and P3.4) created an opportunity to explore multiple new assessment criteria. However, the teams did not seize this opportunity. Even having an explicit creative goal (as in case 1) did not help.

Our within case analyses revealed that not all of the shattering practices were equally easy to detect and manage by the same group. Cross case analyses of the diverse forms of shattering, revealed then action patterns that shed further light on the phenomenon. Some shattering practices, notably diverse forms of protesting, were energetic (e.g. protests in case 1, P1.1 to P1.3), publicly visible (e.g. PRA's public tender aims to

challenge existing solutions, P2.1), and were therefore easily recognizable, and manageable. Other practices, for example sabotaging, were hushed (P3.1), hidden in small-group work (e.g. P2.3, P3.1), not immediately recognizable, and only visible for the managers through their delayed consequences, typically during or after the solution assessment phase (e.g. P1.6, P2.5, P3.4). Some shattering practices, for example protesting and proposing actions, directly addressed the constraint itself as it was understood by the project team (e.g. P1.1, P1.2, and P1.5, O.E.E. definition; P2.1, existing design; P3.1 and P3.4, project goal). Others, for example betraying practices, related only *indirectly* to the constraint by addressing its feared consequences (e.g. P1.4, unwanted changes in maintenance routines; P2.2 and P2.3, suboptimal highway design; P3.2, too-slow railway). In the latter case, it was more difficult to recognize the shattering effects of the practice, seize these effects, and manage the creative reaction.

It is tempting to adopt the labels we used in our analysis, protesting, proposing, betraying and sabotaging to suggest four main categories of shattering practices. Indeed these categories would help to identify the main features of any observed shattering practice. Nevertheless, our data show that most shattering practices seem to be placed in a continuum identified through the two axes open - hidden and direct - indirect, as shown in Figure 1. Some practices present features (e.g. high openness and high directness such as P1.1, or very hidden and very indirect, such as P1.4) that univocally

place them at the boundaries of the continuum. These practices would easily be categorized, using our labels, as protesting practices (P1.1) and sabotaging (P1.4). Yet other shattering practices cannot be caught equally easily by a rigid 2x2 categorization. These are practices (e.g. P2.1, P2.3, P3.1) that simultaneously address more than one constraint with varying degree openness and directness for each constraint. P3.1 is quite hidden, and it addresses C3.1 indirectly and C3.4 quite directly (see table 5). These practices tend towards the center of the continuum and their final positioning is more a matter of interpretation. See Figure 1.

Insert Figure 1 about here

While the dimensions of the continuum are rigidly determined by our analysis, the positioning of the various practices in figure 1, is but one interpretation of how practices observed in the three cases could be placed in the continuum.

The key issue for researchers and practitioners is to be prepared to recognize shattering practices as they emerge in different ways and with varying degrees of openness and

directness against diverse constraints. Whenever observing shattering practices in real life, one can use the continuum in figure 1 to guide and stimulate the interpretation of their features. This guided interpretative effort is a first step towards discovering the shattering, acknowledging its power, seizing the opportunities it provides, and prepare for creative reaction.

Conclusion

This study reveals that in ill-structured problem solving situations constraints may lead to creative action through shattering practices. The opportunities for creative action vary across the observed shattering practices. The more open and direct the shattering practice, the more opportunities for evoking creative reaction. The shattering practices were found in all parts of the problem space, identifiable through their recognizable action patterns. Nevertheless, each of these shattering practices presented unique features, as they resulted from idiosyncratic and unrepeatable organizational settings.

Shattering practices seem to have their own logic, scope, and form. The logic of shattering is one of targeting constraints and releasing disruptive action against them. The scope of shattering, contained in its logic, is limited to challenging the validity of the constraints, and momentarily unchaining whoever is blocked in their tight grip. This

liberation opens the possibility of creativity, but is independent from any preset creative goal. The form through which shattering is enacted is set by its levels of directness and openness.

The practitioner who is aware of these variations constraint shattering has more opportunities to discover and manage shattering as it emerges. Practitioners who identify the space of possibility created by shattering practices can try to steer the creative reaction within that space. For example, during the problem definition phase, possibilities include the potential development of alternative goal states. In this stage, the activities of constraint shattering and creative reaction have remarkable consequences, as both operate at the strategic level of defining the goal state. In the generative part of the problem space, possibilities involve creating new solutions. During the assessment phase, possibilities encompass the potential creation of alternative assessment criteria and widely different views of the goal state. Thus, these insights can be of interest for practitioners engaged in managing creative action in their organizations.

It would be beneficial for both practitioners and scholars to achieve a better understanding of how various forms of constraint shattering are connected to various forms of creative reaction. This is a most interesting area for future research. From a

theoretical point of view, the results of this study show that constraint handling can promote creative action in organizations. The relationship between constraints and creative action must be understood in connection with different constraint handling practices. We have focused on one type, namely shattering practices, i.e. challenging the status quo. There are other known types of constraint handling practices, such as for instance bricolage. It is therefore an avenue for future research to explore different types of constraint handling practices, to see whether or not they contain elements of shattering, and how they influence the relationship between constraints and creative action in organizations. Further, we have investigated the relationship between constraints, shattering practices and creative action in an extreme case situation, i.e. situated practices in engineering problem solving workshops. A future research opportunity is to explore this relationship in other organizational contexts.

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Tables and figures

Table 1: Overview of the workshop cases [a]

ID	Workshop focus	Disciplines involved	Project budget [b]	Duration (days) [*]	Actors (*n*) [c, d]
Creative output was expected					
I	Upgrading manufacturing machines (case 1)	Management, manufacturing, maintenance, mechanics, HR/HSE, quality mgt.	Medium	PD 1, PS 2, SA 1	Client (2), Consultant (8), KIs (3)
II	Design of central station buildings of the capital city	Architecture, construction, finance	Medium	PD 1, PS 2, SA 1	Client (11), Consultant (4), KIs (1)
III	Regional highway design through urban area	Urban planning, highway eng., landscape, architecture, traffic safety, construction, geology	Large	PD 1, PS 2, SA 2	Client (4), Consultant (8), KIs (1)
IV	Tunnel design in railway planning in urban area	Highway eng., landscape, construction, geology, geotechnical	Large	PD 1, PS 2, SA 2	Client (10), Consultant (15), KIs (1)
Creative output was explicitly not required					
V	National high-speed railway development strategy (case 3)	Urban planning, traffic analyses, transportation, railway eng., geology	Medium	PD 1, PS 1, SA 3	Client (9), Consultant (12), KIs (3)
VI	Design of regional light-rail/metro railway network	Urban planning, traffic analyses, transportation, light railway	Medium	PD 1, PS 1, SA 1	Client (10), Consultant (4), Third parties (8), KIs (2)
VII	Assessment of alternative cast-house technologies	Management, metallurgy, mechanics, chemistry	Small	PD 1, PS 1, SA 1	Client (8), Consultant (2), KIs (1)
VIII	Upgrading of a large hydropower plant	Electrical eng., hydraulics, construction, hydrogeology	Medium	PD 1, PS 1, SA 1	Client (7), Consultant (7), KIs (2)
Creative output not expected, but welcome					
IX	Upgrading 20-km highway in a high-traffic	Urban planning, hwy. eng., landscape,	Large	PD 1, PS 2, SA 1	Client (10), Consultant

	area (case 2)	architecture, traffic safety, construction, geology			(13), KIs (3)
X	Environmental engineering design (safety issues at 45 airports)	Chemistry, hydrology, geology, toxicology	Medium	PD 1, PS 2, SA 1	Client (8), Consultant (4), KIs (2)
XI	Planning, regional electric power transportation infrastructure	Electrical eng., transmission, high-voltage systems	Small	PD 1, PS 1, SA 1	Client (7), Consultant (4), KIs (2)
XII	Development of welded tubes technology and related business options	Manufacturing, mechanics, metallurgy, sales	Small	PD 1, PS 2, SA 2	Client (8), Consultant (4), KIs (2)

[a] All cases were workshops run as activities in multidisciplinary projects. * Workshop included 3 phases: problem definition (PD), problem solution (PS), and solution assessment (PS). [b] Project budget: Small < 1M€; 1M€ < Medium < 5M€; Large > 5M€. [c] Third parties are representatives of local think tanks, environmental NGOs, politicians, and similar actors indirectly touched by the project. [d] Key informants (KIs) included clients and consultants.

Table 2. Analytic model used to determine unit of analysis observations from primary data

		Components of practice as unit of analysis			
		Bodily activities	**Things /use of**	**Knowledge/ expressions of**	**Emotional state**
Primary data items	Actors' utterances	**X**		**X**	**X**
	Actors' written notes		**X**	**X**	**X**
	Technical drawings and sketches		**X**	**X**	
	Engineering tools used	**X**	**X**		

Table 3. Scales used to record the level of constraint awareness

Observed form of lamenting a constraint in the group	**Level of openness**
Formally, openly, loudly, orally and in writing	Open
Formally, openly, only orally	Somewhat open
Informally, openly, orally	Medium
Informally, only in minor work groups	Somewhat hidden
Hushed or minor utterances	Hidden

Table 4. Main constraints observed in the three cases

Constraint ID/description	Categorization
Case 1 - Upgrading manufacturing machinery	
C1.1 Project goal: 85% O.E.E. within 2 months	Political
C1.2 Definition of O.E.E.	Technical
C1.3 Low reliability and low operation stability of CTL machines	Technical
C1.4 Investment level needed to achieve project goal	Administrative
C1.5 Project schedule, budget	Administrative
C1.6 Formal organizational hierarchies	Social
C1.7 Interpersonal tensions	Social
Case 2 - Designing a new highway	
C2.1 Project goal: upgrade 20-km highway segment for safer traffic and cheaper design	Political
C2.2 Existing engineering design to be reviewed but not significantly changed	Technical
C2.3 Regional planning laws and requirements	Administrative
C2.4 Building and maintenance costs as budgeted	Administrative
C2.5 PRA's project schedule	Administrative
Case 3 - Strategic HSR planning	
C3.1 Project goal: develop national HSR strategy	Political
C3.2 Customers geographically dispersed	Technical
C3.3 Traditional IC approach influences	Technical
C3.4 Local/national interest conflict	Technical

C3.5 Scope and time allocated to workshop by NRA Administrative

Table 5. Analysis of the constraints shattering practices across the three cases

Practice x.y [a]	**Project phase** [a]	**Constraints addressed**	**Shattering (from case narrative and Table 2)**	**Openness/ directness of disruption (from Table 3)**	**Present/ similar in other cases**
Case 1					
P1.1	PD	C1.2, C1.6	Protest against validity of O.E.E. definition	Formal, open, loud, and direct to both constraints	P2.1
P1.2	PD	C1.1, C1.6	Protest against high OEE level	Formal, open, loud, and direct	P3.1
P1.3	PD	C1.5	Protest against MD's time estimates	Formal, open, and loud/ direct	P3.2
P1.4	PS	C1.1, C1.3	Limiting ideas to already existing solution/activities	Informal, hidden in subgroup work, indirect	P2.2
P1.5	PS	C1.2	New protest against validity of new O.E.E. def.	Formal, open, loud, and direct	P1.1
P1.6	SA	C1.3	Proposing criteria that favor only one kind of idea	Formal, hidden in SA procedures, direct	P3.4
Case 2					
P2.1	PD	C2.2, C2.4	PRA requires higher traffic safety and lower costs	Formal, open, in writing, directly for C2.2, indirectly for C2.4	P1.1
P2.2	PS	C2.2, C2.4	Gr. A produces new but not controversial solutions	Informal, hidden in subgroup work, directly for C2.2 indirectly for C2.4	P1.4
P2.3	PS	C2.2, C2.3,	Gr. D produces only	Formal in writing,	P3.3

		C2.4	controversial solutions, exposes the project to political conflict	hidden in subgroup work, indirectly for C2.3 directly for C2.2/C2.4	
P2.4	PS	C2.2, C2.3	Gr. B produces one very controversial junction design, exposes the project to political conflict	Formal, open in writing, indirectly for C2.3, directly for C2.2	P3.3
P2.5	SA	C2.3, C2.5	Low weight unexpectedly given to criterion "political risk"	Open and directly for C2.3; hidden and indirectly for C2.5	P3.4
Case 3					
P3.1	PD	C3.1, C3.4	Refuse the workshop scope and goal	Hidden in process design, indirectly for C3.1, directly for C3.4	P1.2
P3.2	PD	C3.5	Introduce a work session to force others to prioritize high-speed only	Hidden in process design, indirectly for C3.1, directly for C3.5	P1.4
P3.3	PS	C3.3	Produce only uncompromised high-speed solutions	Open, in writing, directly for C3.3	P2.3, P2.4
P3.4	SA	C3.1	Proposing criteria that favor only one kind of ideas	Formal, hidden in SA procedures, direct	P1.6

[a] Practice x.y provides the case x with item y. [b] PD, problem definition; PS, problem solution; SA, solution assessment

Figure 1. Variation in the expression of shattering practices