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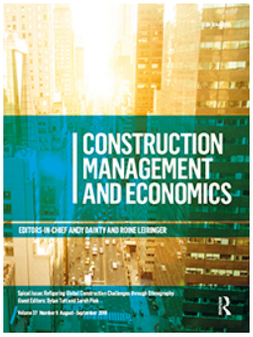

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The production of defects in construction – an agency dissonance

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ABSTRACT

The costs of defects and quality issues in construction can be significant for stakeholders and can include societal consequences. The aim is to address how failures and defects are produced and handled in the social practices of construction projects and specially to scrutinize the unintended consequences of both structured and chaotic problem solving. The argument is based on a longitudinal ethnographic study of a dwelling project, encompassing just over 100 days of fieldwork. Structuration theory was applied to understand the interrelations between project actors and structures in the handling and redressing of quality issues and to elucidate unintended consequences of the practices. The analytical strategy was abductive, allowing theory and empirical material to inform each other. Two cases were selected; the well-structured process of erecting concrete panels and the chaotic processes of building a penthouse. The results show how routine and experience are helpful, but also how they maintain an "acceptable" level of defects, which should change the widespread appreciation of experience as being positive for building quality. The unintended consequences of routinized practices are corroborated by the lack of knowledge sharing beyond the project. Both reactive and proactive problem-solving practices are important, but the reactive tend to dominate.

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Ethnography; building defects; quality; problem solving; structuration

Introduction

Quality issues in the form of failures and defects in building processes and buildings are continuously debated in the international and Danish construction industries on an aggregate level, as well as in relation to specific projects and companies. An estimate by Danish authorities set the annual cost of failures in the Danish construction industry at almost 1.7 billion euros, which is close to 10% of the total annual production value (Danish Enterprise and Construction Agency, DEACA 2004a, 2004b). This corresponds with studies of building projects in Denmark (Apelgren *et al*. 2005), Sweden (Josephson and Hammarlund 1996a, 1996b) and Australia (Love and Li 2000). Despite later efforts to reduce this proportion (DEACA 2009), the Danish, Swedish and Australian industries have largely continued to experience the same level of defects (BEC 2016, Love *et al*. 2016). Moreover, from the micro perspective, defects are a recurrent experience on the building site today (Koch and Jonsson 2015).

There appears to be a practical as well as research gap in understanding how and why defects prevail. Given that there is much research on this including empirical studies, this gap is less of a lack of an empirical grounding and more of a lack of appreciation of the complex social character of the phenomenon. An ethnographic approach is necessary to address this research gap and problem. Ethnography exhibits an openness and strong rapport with action on site and may provide alternative explanations. But merely a more open empirical approach is not enough. A social theory is needed as well, that can provide new angles to processes and practices of actors handling defects in building processes.

The specific purpose here is, therefore, to examine how failures and defects are produced and handled in the social practices of construction management in building projects, and to ask the following questions: What are the roles of problem handling construction management practices in the creation and redressing of failures and defects? What are the unintended

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consequences of both structured and chaotic problem-solving practices? By highlighting problem-solving, this study focuses on something that is often lacking in construction management research, which recurrently seeks to find prescriptive models to account for eventualities on site (Li and Love 1998).

An abductive research design was adopted (Alvesson and Sköldberg 2000). This implies that even if the structure followed here is somewhat linear, the research was rather open, circular and iterative. The theoretical framework adopts structuration theory as central for understanding the social practices of problem-solving (Giddens 1984). The ethnographic fieldwork follows a project that exhibited a number of problems in the processes during construction; yet ex-post is deemed successful in terms of time and money. The group of construction managers comprised of a project manager, production managers for in-house production and other site managers. Two cases are presented and analysed; one involving the assembly of precast concrete elements for a multi-storey dwelling and the other the construction of a penthouse on top. Quality is only one of many considerations and goals that shape and structure the processes. The concrete element assembly serves as a counterpoint to the planning and construction of the buildings' penthouse structure, where processes appear much more unstructured and chaotic.

The research material originates from an industrial PhD project conducted between the university and NCC Construction Denmark – one of the largest contractors in Denmark. An initial review of defects in the industry and within the company revealed a substantial amount of data on the subject. Nevertheless, since a number of specific problems were produced across the portfolio of projects in the company, it was decided that the research should be designed as an in-depth empirical study, i.e. the choice of ethnography as described above.

The paper contributes with an in-depth interdisciplinary understanding of the relationship between structural conditions and the actions and decision-making of site managers on construction projects. Processes leading to failure and defects cannot be seen as isolated incidents but must be regarded as intertwined with the processes that are successful. The key contribution of the study is to expand the understanding of how routines and experiences also can be seen as instrumental in producing and maintaining a certain level of failure. *Reactive* and *proactive problem-solving practices* are found to be important for the completion of the construction project, but problem-solving practices are however forced into being reactive. Paraphrasing Emirbayer and Mische's (1998) aspiration of a chordal triad of agency, the finding here of dominant reactive problem-solving is denoted as dissonance. Where Emirbayer and Mische (1998) argue for a triad of reactive, proactive and "here and now" agency, only one practice is found to be dominant here, the reactive. The *unintended consequences* of routinized practices include lack of knowledge sharing beyond project boundaries, the reproduction of project participants as powerful problem-solvers and the reproduction of an "acceptable" level of failures and defects. These findings together form a significant message to construction management practitioners about the challenges of changing practices to mitigate defects.

Framework of understanding

This study is placed in the context of an understanding of defects and is positioned vis-á-vis prior studies on defects in construction. The positioning serves as a kind of backdrop for the main framework of understanding and is intended to support the development of an answer to the purpose and research questions. The positioning and framework are developed in four steps. First, the positioning through previous studies is done. Second, it is posited that agentic processes of handling defects can be understood as a structuration process. This process involves the third step, agency, which is developed by combining Giddens (1984) with Emirbayer and Mische's (1998) theory of agency, which then leads to the fourth step: understanding of the agentic processes of handling problems related to defects, and understanding them to have two main forms, proactive and reactive problem-solving.

Previous studies on defects in construction

Approaching the phenomenon of defects in buildings is complex and multifaceted. A defect can be understood as a fault or imperfection, but relative to what? The technical definition of defects as a deviance from design specifications is frequent in quality literature (Dale 2003, Love *et al.* 1999, Love *et al.* 2016). Technical and quality approaches to defects are aligned in the belief in a full and coherent specification, and faults, therefore, are assumed to be easy to identify (Forcado *et al.* 2014). Yet, empirical studies of construction, which follow the process of production of defects find that the design, including technical design is often incomplete, and therefore renders

open what reference a possible deviance would refer to (Apelgren *et al*. 2005, Thuesen 2006). Quality literature adds the important aspect of process to defects, pointing out that quality problems can relate to product features as well as the processes, thus leading to an additional focus on rework (Dale 2003, Jraisat *et al*. 2016, Love *et al*. 2004). Defects also have a social and economic aspect since, in a building project, someone will be held responsible for a defect and will be requested to pay for the needed rework (Schultz 2012). Some scholars argue for viewing defects as an unpredictable, random phenomenon (Kreiner and Damkjaer 2009). Finally, critical observers point to the socially constructed and negotiated aspect of defects (Schultz 2012, Kreiner and Damkjaer 2009).

Research on defects, errors and rework has been carried out (Apelgren *et al*. 2005, Josephson and Hammerlund 1996a, 1996b, Li and Love 1998, Love and Josephson 2004, Love *et al*. 2016) in which technical rational approaches to causation are often developed that assume that building sites can be understood as systems. The cost of defects is an element in most of these studies (Abdelsalam and Gad 2009). Some studies rely on databases of collected defects made by sector players, introducing uncertainty on the validity of data (Forcada *et al*. 2014, Hopkin 2016). In construction management handling of defects and related problem solving is often conceptualized based on cognitive psychology or decision science (Li and Love 1998, Loosemore 1994, Love *et al*. 2016). Yet, Li and Love (1998) describe construction problems as ill-structured and loaded with uncertainty. Moreover, defect studies tend to adopt a methodological individualism creating serious limitations to our understanding (Lukes 1968), for example, through an over-emphasis on human error as an explanation (Love and Josephson 2004), pointing to poor workmanship on site (Forcada *et al*. 2014, Josephson and Hammarlund 1996a) or through leaving unproblematized whether the actions intended to solve problems actually do lead to solutions (Jraisat *et al*. 2016). Rarely is sociological theory mobilized to appreciate either the complexity of decision processes in construction or the intersection between structures and human agency, understanding structures as both enabling and constraining social actions.

Structuration theory

As argued above defect studies need to be enriched with social theory beyond methodological individualism. This can be done using structuration theory, the theoretical angle of which leads to the adoption of a longitudinal ethnographic study as explained in the next section.

The central idea of structuration theory is to view social practices as an on-going intersection between structures and agents (Giddens 1984). Social practices are viewed as recursive: structures are the medium as well as the outcome. Agents, in turn, are understood as being knowledgeable: they can draw upon structures and are at the same time both enabled and constrained by structures. Structures are understood as rules and resources and as both external (e.g. corporate) and internal (relative to the agent). When agents act, they can do so in a reflective, discursive manner or a more routinized manner, giving the structuration processes of forming new structural elements a more or less reproductive character. Social practices in agentic processes, in turn, can lead to intended or non-intended consequences.

Structuration theory is a grand theory operating at a broad ontological level, i.e. it is intended to understand the constitution of society. Adopting a strong structuration theory (Stones 2005) enable the use of structuration in particular contexts:

> Strong structuration is bridging concepts between philosophical and substantive levels of structuration, to develop not only and 'ontology in general', but also an 'ontology in situ' directed at the … particular social processes and events in particular times and places (Stones 2005, p. 8).

Strong structuration introduces a meso-level of ontology between the abstract, philosophical level of ontology and the in-situ, ontic level (Stones 2005, p. 84–85). A systematic use of the abstract concepts is ensured by making the meso-level explicit, allowing the possibility to apply the general ontology as ontology *in situ* in relation to case studies. Strong structuration also introduces the quadripartite nature of structuration (Stones 2005, p. 85) detailing the elements in the duality of the structure. On the structure side, it includes a distinction between external and internal structures. External structures are conditions of action. Internal structures "operate" within the agent. To this active agency and outcomes (as new or maintained structures and events)is added. Adopting strong structuration further allows a conceptualization of agency and agentic processes of micro character. Giddens (1984) posits that knowledgeable agents are central to social practice and structuration processes. The strength of Giddens' conceptualization of agency lies in the open combination and double possibility of either routinized unreflective action or conscious

reflective liberation of structural constraint in order to commence action. The subsequent structuration includes problem-solving and learning, not only by the agent but also in social orders and structures (Boreham 2008). Structuration encompasses more than learning and problem solving, particularly in relation to the unintended consequences of structuration processes where the reproduction of practices differs from learning and where conscious problem solving requires an element of change.

Here, Emirbayer and Mische's (1998) critique and extension of Giddens is important. While their conceptualization of agency is largely aligned with that of Giddens, Emirbayer and Mische (1998) argue that there is a tendency in structuration theory to underline the unreflective routinized element and to downplay the reflective (where other critics actually argue the opposite, see Stones 2005). Moreover, forward-looking, creative and constructive agentic processes could be more conceptualized, than with Giddens, they claim, introducing and conceptualizing the projective element in agentic processes. Emirbayer and Mische (1998) view agentic processes as characterized by three dimensions relating to past, present and future, corresponding "to the temporal orientations of agency, allowing us to examine forms of action that are more oriented respectively to the past, the future and the present" (Emirbayer and Mische, 1998, p. 971). They combine these three elements in the chordal triad of agency: iteration, projection and practical evaluation (ibid, p. 970), using a musical metaphor for the interdependency of these three elements, while underlining that the three would have different strengths in different contexts. The iterative dimension is very close to Giddens' unreflective reproduction of existing practices. The practical evaluation also appears close to Giddens' view on social practices, whereas the projective dimension is defined as the "imaginative generation … of possible future trajectories of action" (Emirbayer and Mische, 1998, p. 971) and can be mentioned that this is further conceptualized as the subsequent three agentic processes of "anticipatory identification" (ibid, p. 989), which relates to understanding the unclear and flexible structure of future possibilities, "narrative construction" (ibid, p. 989), that relate to developing a sense of movement forward in time, and "symbolic recomposition", where actors playfully place themselves in possible trajectories of the future. These three elements give further understanding of the projective dimension, which is the most important extension of Giddens.

Summary of framework

Defects and failures are ill-defined, constantly negotiated and multifaceted. They exhibit, at minimum, technical, economic, institutional and symbolic aspects. Even if this ill-defined character is challenging and problematic, it is contrasted by a large number of occurring -very concrete- defects on building sites, where a negotiated, blurry definition of a defect is less of an issue. Social theory is needed to understand building processes for handling defects, rational decision-making models and systems theory approaches fall short of understanding these processes. Strong structuration theory is therefore adopted, to understand action in the context of social practices and with agents taking proactive or reactive action to solve problems occurring from defects. While agents aim at problem-solving, they do not always arrive at a solution, and unintended consequences are prevalent. The agency can, according to Emirbayer and Mische (1998), be understood as three elements in a chordal triad: iteration, projection and practical evaluation.

Methodology

The research issue is to examine how failures and defects are produced and handled in the social practices of construction management and to understand the unintended consequences of both structured and chaotic problem-solving practices. An appropriate methodological design is necessary, and the paradigmatic positioning of this study is primarily interpretive sociological in order to compile the framework and support the fieldwork and analysis. The design encompasses an interdisciplinary approach including elements of an engineer-scientific approach applied to understand the rationality of (engineering) management, the habitus of engineering as well as planning as a practice.

The research project is designed as an abductive research process where theory and empirical data inform each other in iterations. Based on Alvesson and Sköldberg (2000), a reflexive qualitative methodology is adopted with interpretation on four hermeneutic levels, acknowledging the need for various types of interpretations. Three main iterations were carried out: first following single defects; second using a structuration approach and third, focusing on problem-solving.

The theoretical framework combines processual elements with elements of stability (structures) through Giddens' theory of structuration (Giddens 1984). A study of the preconditions of actions demands an in-

depth scrutiny rather than a broader approach, so a single-case design was selected. Single-case studies "when compared with quantitative research or multiple case studies [are] ordinarily judged to be lacking in rigor, comparability, and replicability" (Barzelay 1993). However, the method is extremely valuable for social science research when used for purposes of analysing how people frame and solve problems (*ibid*.).

Importantly, processes of defect handling also invite an open ethnographic approach (Alvesson and Deetz 2000, Pink *et al*. 2010). The research takes the position of appreciating processes, viewing them as being emergent and having a potential for change. This appreciation leads to the adoption of a longitudinal approach (Giddens 1984, Pettigrew 1997). Since the point of interest is the occurrence of defects in building and their causes and mitigations, and since these unravel over shorter and longer timespans, a more snapshot-oriented approach would risk missing important elements.

Literature

The literature selected here used to position our study, stem from several consecutive searches and studies done over the years 2008–2018. The intention here is to provide a backdrop for our ethnographic study.

Selection of building project and cases

The building project was selected after an initial study of the host company's warranty case documents. These showed that dwellings did exhibit considerable issues with defects. Dwelling building activities were also an important business area at the time. A dialogue was carried out with company representatives about possible projects, to study, that were in an early phase. A meeting with those involved with the candidate project confirmed the possibility for access as well as phenomena to study. The two cases discussed in the paper are selected ex-post to correspond with our specific aim and argument. They are picked from among the four cases analysed in the thesis. As described below under method for analysis, the four cases emerged as part of the abductive research process. One of the cases selected involves precast concrete assembly, and the other the building of a penthouse. These cases are in contrast to each other analytically, as the first exhibits mundane practices and reactive problem solving, while the other case is far more chaotic and full of proactive search processes.

Ethnographic fieldwork

The empirical material consists of a 15-month ethnographic field study comprising workplace observations, formal and informal qualitative interviews, and a collection of written background material. Corresponding to Dingwall in Cicourel (1964), the strategy for gathering insights about the field of research was "hanging out" and "asking questions", "reading papers" and asking "native questions" (Spradley 1979). In total, a little over 100 days of ethnographic observations of primarily on-site processes were conducted between autumns of 2007 and 2008. Onsite attendance amounted to a few days a week, on average. Attendance was partly planned and partly stochastically distributed. Presence was prioritised at what were deemed to be important times in the context of the selected cases, for example when the building parts were erected when defects where redressed or at meetings. However, attendance was affected by what was practically possible. The fieldwork primarily focussed on site management activities and the work tasks of the contractors' project team. The site management team consisted of an overall project manager, production managers for in-house production and other site managers, i.e. all participants in site management. The fieldwork also covered interactions with designers, suppliers, subcontractors, craftsmen as well as representatives of functions at the headquarters. All observations at other locations than the site, such as a study visit at the suppliers' facilities, were made with the site management.

The ethnographic study was longitudinal, as the work on the building site developed from groundwork to building structure, to installation. The studied social order was therefore emerging and saturation less obvious to obtain. Similarly, the fieldwork, therefore, iterated from being more open to being focused and selective (Spradley 1979). When focusing on a particular defect, it was often an advantage, through observation on site, documents and engineering background, to be able to ask native questions, that is with reference to occupational profiles (i.e. craftsmen), materials, methods and equipment, but also to issues derived from rationality of management, the habitus of engineering as well as design, planning and production as practices.

The role of the researcher as an observer and at the same time an employee in the company doing

the building project was continuously negotiated. In the context, it was often an advantage to be able to accentuate different perspectives in gaining access to the often delicate topic of "defects" and to gain the trust of the people studied, such as those of a researcher, the contractor's employee and engineer. The employment relation of the researcher also resulted in certain restrictions and limitations regarding access and trust, however, for example, the project manager often expressed himself very politically in relation to central company structures, which is interpreted in the analysis as biased and as a deliberate attempt to influence company structures through the research project.

The engineering background of the researcher, as well as other background knowledge, could also be a barrier to an open, curious and listening approach. Based on Alvesson and Sköldberg (2000), a reflexive qualitative methodology was adopted with interpretation on four hermeneutic levels, acknowledging the need for various types of interpretations, and including reflection about the researcher's own role. The aim of this process was to systematically address the researcher's pre-understanding to explore potential biases, such as through writing down assumptions and then critically evaluating the theoretical background of the given assumption. The new insights were continuously retested in relation to subsequent empirical observations. In the primary round, the fieldwork was documented in 120 densely written pages of the diary, minutes from a series of meetings (site management, quality control, health and safety, ad hoc meetings) and a collection of numerous types of documentation such as drawings and plans for the building work and photos.

Interview

Three overlapping types of interviews were carried out. First, while present at the building site, numerous informal dialogues and interviews were integrated into the fieldwork. Here, the interviews benefitted from established rapport and had the character of friendly conversation, building further on respectful on-going relationships; these could be called ethnographic interviews (Heyl 2001, Spradley 1979). Second, formal semi-structured interviews were also carried out with the project manager on site and the contract managers. These semi-structured interviews could, like the ethnographic interviews, draw on already established relationships, and questions could be further developed based on previous events and dialogues. The third type comprised 12 more formally arranged interviews, carried out in a semi-structured fashion. Interviewees here were staff members at the contractor's headquarters, consulting architects and engineers. These interviews were the "one-off" type.

Documents

Documents comprised drawings, technical descriptions, meeting minutes (formal) and correspondence (e-mail) collected to support the ethnographic work while responding to the research question.

Analysis

The qualitative abductive research process implies that theory and empirical findings inform each other in iterations (Alvesson and Sköldberg 2000). In the research on which this paper is based, the analytical starting point was the constellation of empirical phenomena of defects and the theory was Giddens' (1984) structuration theory. The theory acted as an eye-opener as defects occurring on site were collected and as the processes that evolved "around" them were followed through an open longitudinal ethnographic study. This collection of defects and related processes were selected and documented in a rather descriptive manner in what is denoted as the first analysis. Any divergence between the theory and empirical findings was discussed through continuous iterations. Alvesson and Sköldberg's (2000) reflexive qualitative methodology stresses the need for various types of interpretation. The focus of the second analysis became social practices, even those that were recurrent. This new organisation of the fieldwork led to a focus on four processes that occurred for handling problems, which were then conceptualized with the problem-solving constructs. These four processes became four sub-cases and were written up extensively using the material collected. The text of the second analysis consists of diary excerpts, excerpts from documents, photos and quotes from actors. In total, this second analysis comprises 130 pages. The third analysis more rigorously mobilizes structuration concepts, drawing on Giddens (1984), Stones (2005) and Kaspersen (2006) and integrating problem-solving and learning into structuration. The third analysis cut across the cases, gradually developing an understanding of the role of the social practices. The fourth analysis involves a closer focus on agency practices, using Emirbauer and Mische (1998).

Table 1. Precast concrete supplies and recurrent problems.

Supplier	Type of precast concrete elements	Number of registrations in the contractor's reception control	Typical problems
1	Floor slabs and light inner walls	60	Non-approved lifting inserts Tilting electricity wall plates Lacking corrugated pipes Lacking wire locks Recesses lacking or too shallow
2	Heavy tile facade elements	37	Non-approved lifting inserts (estimated total 35 pcs (only registered as one point)). Missing wire locks Corrugated tubes compressed, skewed and / or incorrectly positioned Wrong dimensions Mounting of extra pipe supports on facade elements
3	Concrete staircase elements	4	Faults on electrical inserts and power lines Repos in the basement is not molded to the wall Damage on delivery

A series of limitations must be recognized. The paper posits learning as an exemplary structuration process (drawing on Boreham 2008) but does not further develop this conceptualization. During the field work, not all defects occurring during the researcher's presence on site were registered, since it was not possible to pursue all parallel activities of craftsmen, site managers etc. In addition, the vast number of impressions and massive amount of data can induce "death by data suffocation" (Pettigrew 1997); it is also difficult to present the nuances in the empirical data and analysis in the form of a journal paper. Moreover, the documents and e-mails used in the initial write up are all in Danish. The possible bias of the investigation as a result of the researcher being employed by the company has been included in the analytical reflections. However, the industrial PhD programme setup and the involvement of research institution-based academic researchers and supervisors should also limit this challenge. This is written several years after the PhD candidate left the company and is furthermore a joint production with one of the supervisors, which brings further analytic rigour and strengthens the analytical approach.

Case 1: the pre-cast concrete element assembly

The first case includes a series of everyday processes involved in the assembly and erection of precast concrete elements as well as a large number of "ordinary" small problems and defects in the processes. The structural design project was modelled in 3D and handed over to the precast concrete factories. The carcass structure was based on different types of precast concrete elements corresponding to three different suppliers of various supplies to the site. The many small recurrent problems are illustrated in Table 1.

The carcass was erected by an in-house team that worked as a regular sub-contractor on the project. All the different contributing parties were involved at some point in the initiation of a large number of failures in the process of erecting the elements. Failures and defects were related to planning, the structural engineering project (although this was evaluated by the on-site team as having an unusually high standard), the suppliers and their factories, on-site management as well as personnel management and production management that were active during execution. Production flaws initiated by the concrete element suppliers were common, in the form of misplaced recesses, joint locks, inserts etc. as well as slanting elements and problems of keeping within the tolerances. An example is the corrugated pipes, which reinforce the building vertically and caused recurrent problems during assembly:

> On the deck of the first floor, it can be seen that all corrugated pipes have been pressed flat. The crew was asked by the foreman how many elements they have managed to install, and they explain that they managed to install 11 elements today. One-member notes, 'We mounted them all twice, so that's 22'. The foreman later describes the suppliers' quality control as too sloppy. He stated: 'They are in a factory, and they leave it up to us' (Excerpt from diary).

A similar pattern occurred with the deliveries of the two other suppliers. As an indication, a total of 101

defects of this type were reported in the quality assurance system during the precast concrete assembly. Some of these are multiple on-site defects, such as the absence of inserts. Other defects, such as too long elements (1–2 cm too long), are less rigorously recorded on site because the supplier is within promised tolerances. Once the defects occur, the processes are roughly recurrent. The assembly crew discovers the defect, and they inform the production manager on site, who is their immediate liaison to site management. When the production manager becomes aware of a problem, the problem is documented, often supported by a photo and a short description, which is typed into a spreadsheet back in the site hut. The problem is reported to the element supplier, and it is decided who is responsible and who will redress the problem. If an agreement cannot be reached, the production manager initiates the redressing, and the discussion of responsibility and expenses is put on hold until later. This practice secures the progress of the production, which is considered vital. At some point, there are three "finishing crews" from different suppliers present at the site in addition to the original concrete assembly crew. Upon the completion of the project, the parties reach a final financial agreement to cover the expenses.

The otherwise mundane assembly process was also interrupted a few times by larger defects, including examples of extemporaneous problem-solving. The three main incidents are the following:

- During the assembly of indoor walls on a particular floor, it was revealed that five elements were missing. This was due to a design error (the cut and paste of design objects in the BIM model).
- When a crane was lifting the heaviest elements into place, the crane's alarm for overweight protection was set off. The crane operator tried to bypass this protection, but it almost made the crane tilt. It turned out that the elements weighed 30% more than they were designed to (the accepted weight tolerance is 10% from the supplier). There were big discussions between the site crew and the foreman about the size of the crane. The first improvisation was to turn the crane's caterpillar tracks 90 degrees, but the crane's alarm for overweight protection began again. Then, the foreman thought to fill up the trench next to the building in order to allow the crane to drive closer, but this did not prove to be possible. Finally, the foreman chose to rent a truck crane to handle the four heaviest elements on the far side. This proved successful and was repeated a few times later in the element assembly.
- A façade element fell from its temporary fixation in the building wall and caused the fatality of a construction worker.

The many recurrent defects occurred over a period of seven months from November 2007 to June 2008. The tilting crane defect occurred in November, the fatal accident in January, and the five missing inner wall elements defects in May.

Case 2: the building of the penthouse

The process of planning and construction of the building's penthouse commences in a structured manner. It is well established by the project manager and by the contractor that the water tightness of the penthouse is critical and involves various risks. Based on previous experiences in the company, the project manager assesses this part of the building to have the highest risk in the project. The penthouse storey is designed with heavy load-bearing walls and concrete slabs as a roof. The building envelope is steel-clad sandwich panels with a core of insulation. A range of lightweight concrete walls and plaster walls function as partitions. A semi-interior terrace is placed at the rear of the penthouse with a steel railing and a steel cover for the sun. In the processes, a number of actors are present, two carpenters, a concrete contractor, the roofer and a blacksmith. The project managers have no experience with tightening the building envelope of a penthouse. Aware of their lack of competencies, they try to plan the processes meticulously prior to the execution. They review the project material, and at a meeting, they try to uncover all possible problems by dividing the processes into small parts using post-it notes. They also visit the supplier of the steel-clad sandwich panels to gain knowledge about how to execute the processes. However, A number of problems arise in the execution phase. An initial problem arises when the roofer hires a sub-contractor who does not follow the instructions agreed upon by the project management and the original roofer. The biggest problems arise, however, when it is discovered that the construction is leaking. A major rain shower reveals that the joints in the penthouse construction are indeed problematic as they are not tight. Water is detected in several apartments on several occasions. A "Blower Door" test also shows that the construction is leaking. Over a period of many months, the actors try to solve the problems, and site management allocates quite some resources to the issue. Directed by the site managers, the actors try to find a number of possible

solutions in as organized a way as possible. There are repeated adjustments and rework before the construction is considered tight enough to meet the requirements. At one point members of site management discuss possible solutions in their office in the site hut:

> One manager wants to use joint-sealant at the leaky places. The others are worried that moisture is enclosed in the structure if it is too tight, noting that 'there will always be moisture in the structure'. The first manager insists that moisture is not an issue if sealing is done properly (Excerpt from diary).

A specialized independent sealant contractor is hired and it appears that tightness is improved considerably. Yet the problem persists. Finally, after a number of corrections, they succeed in making the construction tight, by using additional screws and sealant, additional layers of roofing felt, and an extra focus on the quality of the interfaces. When the project is finished, however, they are still not aware of the actual causes of the ingress of water.

Analysis

Failures and defects are produced and handled in the social practices of construction projects in particular ways. The aim here is to analyse the role of problem-solving construction management practices in the creation and redressing of failures and defects in order to determine the unintended consequences of both structured and chaotic problem-solving practices. This section first analyses each of the two cases in relation to the research aim. Then, the cases are analysed in a cross-case manner from a structuration point of view. The discussion subsequently places the cases in the context of the building process across the many incidents of defects and problem-solving practices.

The precast concrete assembly

The problem-solving practices in the precast concrete element phase can be described as very routinized. Planning practices precede production practices, which then occasionally involve problem-solving practices. Production failures are detected when an involved actor (often a worker in the assembly crew) is somehow triggered to reflect on the quality of either the product (e.g. the concrete panels) or the processes. Their reflexive monitoring perceives that something is not as expected. Moreover, assembly crew members and site management almost expect the elements to be flawed since a number of defects are recurrent. In this case, the production managers' routinized process of problem-solving is even structured and supported by corporate structures in the form of formalized spreadsheets and procedures aimed at addressing (expected or unexpected) problems related to the suppliers. This process is also included in the contracts and is thereby closely linked to the responsibilities of the actors. It is in this manner, formalized with respect to both the external and the internal structures relative to the agents. This is a consequence of highly standardized processes; the processes and the product resemble many other traditional housing projects in the company.

The three exceptions or larger failures or defects described above (i.e. a tilting mobile crane, the missing indoor elements, and the fatal accident involving a construction worker) could maybe be expected to demonstrate other problem-solving practices. However, only the fatality leads to proactive problem solving, which takes the form of changing formal company procedures. The accident pushes everyday problems aside and tests structures and practices to the extreme so that in this case, the routinized practices are changed. The accident led to sorrow, remorse and feelings of guilt amongst the fellow building workers, but it also led to a number of revised recommendations in the concrete element association's industry guide, which influenced the industry in general and the suppliers in particular. It led the company's safety council to revise the company's procedure for assembling precast concrete walls. It also triggered the issue of notices from the Health and Safety Executive, and to attention from the police and the executive echelon of the company (all of whom visited the site).

The problem-solving processes combine cause analysis and placing of responsibility. If a supplier is prepared to accept a rework, the unintended consequence is often that the reasons behind the defects are not further explored (Giddens 1984). Given the constant focus on progress in the precast concrete assembly process, it is vital to decide who is responsible for redressing a failure. Hence, placing responsibility becomes more important than understanding the causes. A similar unintended consequence occurs when the tilting mobile crane is interpreted by the blue-collar workers as a symbol of too much focus on cost cutting from the white-collar employees and managers. The inadequate crane becomes a central symbolic resource to the blue-collar workers for an entirely different action – a wage labour conflict. The blue-collar workers argue that their superiors only focus on the financial result paying substandard wages and don't care about the wellbeing of the

employees. Finally, this illustrates the multifaceted conceptualizations of defects that are negotiated among the actors and underlines the difficulty of providing a comprehensive definition.

The building of the penthouse

The initial proactive planning exhibits what Emirbayer and Mische (1998) call agentic processes of anticipatory identification or projective agency. The actors face a potential future problem that is unique. They have not built this type of penthouse before, and in the company and the project group, they are aware that penthouses (in general) have had issues with tightness. The actors therefore mobilize a projective imagination and plan the project meticulously, including how to coordinate the different craftsmen involved. Soon, however, the substitution of a contractor leads to deviation from the plan. When leaks are discovered, the actors shift to an improvised practice, which actually is a complex intersection of three practices – planning, problem-solving and production – which can be viewed as "practical evaluative" (Emirbayer and Mische 1998). These three practices also tend to fragment at one point, as well as to overlap. It is only by chance that the leaks are discovered at all: it starts to rain, twice! Causes can be related to gaps in the entire range of communication, skills, knowledge and execution. In addition, the project manager does not seek advice from company headquarters. Nevertheless, in the end, the actors appear to solve a problem without understanding more than only some of the causes. The processes of problem-solving can be described as being highly chaotic, in spite of the site managers' attempts to organize the work procedures. This can be seen as a consequence of the processes as well as of the final product (the penthouse) being relatively unique and unstandardized.

It also caused an unintended consequence since the entire process could provide important learning for actors and the company; but it remains unclear under what circumstances the solution for this particular penthouse can be used: When will it work and when will it be useless?

Cross case analysis

It is now time to analyse the two cases together. These cases illustrate how quality issues pervade construction management processes and practices. The quality-handling practices in construction management exhibit all parts of structuration, which include structures, knowledge agents, structuration itself, and unintended and undesirable consequences, and they occur in an intertwined, complex manner. This analysis considers the cases element by element. Both external and internal structures are at play in the two cases. External structures include guidelines for processes, equipment and performance data sheets (i.e. the crane). Internal structures include formalized spreadsheets and contractors' procedures aimed at addressing (expected or unexpected) problems related to suppliers. The project staff draws on a varied, nuanced network of abstract structures. Corporate structures are often omitted or are used in a different way than originally intended; specifically, "quality structures" (i.e. internal as well as external, relative to the agent) often prove to be peripheral. In the first case, there is a rather strong hierarchy among structures (Giddens 1984, Stones 2005), where responsibility, progress and cost have high priority and quality and work environment have lower priority. This is expressed directly by the managers' actions and derives from contracts, schedules, and budgets. In the second case, managers navigate among structures such as external guidelines and norms and previous experiences, which are contradictory structural framing of the actions.

Failures and defects are mostly considered by knowledgeable agents to be consequences of something unexpected or unforeseen, but during the concrete element assembly, it was routine to expect defects. In both cases, breakdowns in the processes, such as defects, are illustrative of how conscious or unconscious reflection by the agents leads them to identify when a problem, failure or defect might occur. It is the specific phenomenon of the failure, defect and/or problem that is investigated, as well as the previous actions, processes and structures that affect the incident, and also the ex-post effects in terms of consequences for both actors and structures. In the precast concrete element project, a dedicated engineer is assigned to project engineering, which is not the case in the penthouse project. Therefore, in the penthouse case, there is weaker professional anchoring, and the quality of the processes becomes highly dependent on the project competencies. Because of the differences in the processes (e.g. the many interfaces between various sub-contractors as well as the different materials), a different set of knowledge and competencies is required than in the case of the precast concrete project.

The precast concrete assembly case contains examples of firmly established hard-core routines and practices in the construction project that lead agents to restructure practices that produce failures and defects. Failures and defects are thus unacknowledged conditions of the actions. It is interesting that at first glance routines and experiences seem to help to reduce the number of failures, but a closer inspection shows that the very same routines can also be seen to maintain a certain failure level, through the unintended consequences of agents' actions. Problem-solving as a routinized practice thus has effects beyond the individual decision maker. This highlights the limitations of previous defect studies, which draw on cognitive design-making models (Li and Love 1998).

The problem-solving processes in the two cases fall into two main categories: those parts that relate to the correction of defects and failures often take the form of *reactive problem solving*, while other activities can be described as *proactive problem-solving*. Reactive problem-solving practices are highlighted as being important for the realization of the construction project and for ensuring that planning and design are achieved in the finished project and that the project meets the clients' demands. Problem-solving practices are often forced into reactive problem solving, leading to a chordal dissonance, to paraphrase Emirbayer and Mische (1998). Moreover, the research project shows that not all failures can be traced back to the design, engineering or planning (proactive problem-solving practices). The two cases described here show that on-site staff and construction managers are often uncertain and that they vacillate about the premises, causes and consequences of their choices and actions in their problem-solving practices. Although problem-solving activities are organized and structured in practice, their importance is often neglected in the planning paradigms underlying most construction process planning.

Discussion

The study points to how the agents – in the business as well as the industry – are affected by the experiences of the specific construction project, highlighting that the only time the experiences of the construction project go beyond the project boundaries is in relation to the fatal accident. It should be remembered that the problem-solving practices involved in this failure have not been analysed here. It is paradoxical that the consequences of the failure or defects must reach such an extreme before bringing about a change of methods and social practices in the construction industry. It is also highlighted that the local agents actually learn from their experiences and the processes, but their knowledge of specific solutions is diluted because they either are dismissed, move to other business areas or change jobs after project completion.

Both visible and invisible power relations occur in the project processes. The project manager dominates and shapes the problem-solving practices, executing his "quiet" invisible power to the inexperienced or less experienced project participants amongst the site managers. This becomes an important element in a prolonged structuration and prevents an autonomous problem-solving practice, which is considered to have major negative consequences for the company, both financially and socially. Problem solving is a repeated activity that pervades most construction processes and that can be considered as a social practice and moreover as the project staff's general disposition (or habitus) – as internal agent-related values. The latter becomes relevant when considering how the agents prioritize quality in relation to other dominant structures, for example earnings/budget, time/schedule and/or responsibility/contracts. The social practices are structured by actors' dispositions and their context-specific knowledge (internal structure) and are sometimes also supported by external structures.

Structurally, there is a contrast between process engineering incentives and economic incentives: "economy" and partly "progression" (in the form of scheduling) become dominant structures, while quality is considered to have a lower priority. "Quality" and "responsibility", as structures, become to greater extent elements in efforts to achieve economic results and comply with schedule. Quality is only one of many considerations and purposes that shape and structure the processes. Other structures, like time and money, become predominant, and previous individual or project-related experience can also be structurating. These are highly dominated by individual experiences or experiences in the project network and are seldom based on organisational experiences. Often, the structures have an impact on the direct sense of value for the individual or the project. This more or less conscious selection of structural elements is also based on the experiences of the actors and the project network, and can be seen to a great extent as a social construction, affecting the selection and deselection of the structures at hand. Moreover, direct procedures, orders or commands can be structurating. In contrast or collaboration with incentive structures and rewards, they

create a tense space for the actors to manoeuvre in. These characteristics can be seen as elements of project cultures that are highly resistant to outside interference.

Knowledgeable agents and unintended consequences

The problem-solving practices in the two cases (and the project as such) form a continuum from structured problem-solving activities to a large number of more chaotic and unstructured processes. The research project on which this article is based considers that problem-solving processes occur during design, engineering, planning and production. Both "extremes" of problem-solving have different starting points and introduce a number of *unintended consequences*. The well-structured problem-solving practices that occur in the case of the precast concrete element assembly introduce problem-solving as a relatively pragmatic practice that does not address the causes of the failures and defects. In this way the on-site problem-solving strategy does not handle the underlying structures but only solves the manifested problems on a short-term basis. At the opposite end of the spectrum, one of the unintended consequences of the unstructured problem-solving practices is that the on-site staffs – in spite of the problems – reproduce themselves as strong problem solvers who are able to solve all problems themselves without seeking solutions, skills or competencies elsewhere in the company or industry. This can be seen as a hindrance to organisational learning as a particular type of structuration. According to Boreham (2008), an organisation learns when organisational experiences are codified as new norms and procedures and when employees internalize these new norms. However, in this case, the knowledgeable problem solvers neither store project experiences in external corporate structures, nor do they draw on the quality structures from the main organisation.

Looking across the entire field of study, the well-organized as well as the unstructured problem-solving practices, contribute to reproducing the notion that a certain level of failures must be expected in the construction processes, that is, – *an acceptable level of defects*. The agents' *reflections* on the underlying causal structures can, therefore, be described as limited, and this inhibits the exchange of experiences, learning and quality concerns in the processes.

Theoretical aspects

Theoretically, the study supports and contributes to an understanding of the relationship between *structural premises* and *agents' actions* and their consequences. It demonstrates how a sociological perspective can provide important insights in the analysis of failures and effects in a departure from traditional causal analysis, since it also includes the non-individual, structural and unintended consequences of the agents' social practices. As the empirical analysis unfolds, it exhibits a strong emphasis on routinized non-reflective reactive problem solving, which is interpreted here as an empirical result. Moreover, the research shows that not all failures can be traced back to the design, engineering or planning (the proactive problem-solving practices). The emphasis on reactive problem-solving leads to a chordal dissonance, to paraphrase Emirbayer and Mische (1998), who claim that reactive, proactive and improvisation types of problem solving make a harmonious triad of agency.

The overemphasis on routine and reactive problem solving accentuates the recognized risk of central conflation (Archer 2000) in structuration theory, overdoing the (constraining) influence of structure (Emirbayer and Mische 1998). The *knowledgeable agents* are very "visible" in the processes, with different prerequisites to achieve their results. The results can best be described as mixed. The role and importance of different *structures* in the quality of the observed project processes are highlighted; the project staffs draw on and are constrained by a varied, nuanced network of *abstract structures*. Problem-solving is considered as a *social practice*, but also as the project staffs' general-disposition and as internal agent-related values. The interrelationships between structures are understood as being potentially contradictory, sometimes pluralist and/or hegemonial, i.e., in a prioritized type of hierarchy, and the findings show that such a hierarchy often seems to be present, where some structures are more dominant than others. However, the interrelationship of structural elements occurs here in a context-dependent manner, where the agents are important. There *is* room for occasional proactive action, but the actors must constantly consider a number of constraints.

Conclusions – agency dissonance

The specific purpose of this study is to examine how failures and defects are produced and handled in the social practices of construction projects, and to ask the following: What is the role of problem-handling

construction management practices in the creation and redressing of failures and defects? And what are the unintended consequences of both structured and chaotic problem-solving practices in construction management?

A framework of understanding was developed that corresponds with this research aim: strong structuration theory, with a conceptualization of agency that underlines proactive and reactive problem solving as social practice. To obtain the necessary open empirical approach, a longitudinal ethnographic study was designed, encompassing just over 100 days of ethnographic on-site observations as well as interviews and document analysis. In this process, the role of the ethnographer was constantly negotiated and the building engineering background knowledge was used in a reflective manner. The two cases selected from the longue durée (Giddens 1984) of the building project were presented and analysed, exhibiting through contrast the importance of reactive and proactive problem-solving practices. One case with well-structured practices was contrasted with another, chaotic case.

The well-structured problem-solving practices are relatively pragmatic and the causes of the failures and defects are not addressed. The on-site managers reproduce themselves as strong problem solvers, in addition indirectly hindering organisational learning. The significance of reactive problem solving is found to be neglected in the planning paradigms that underlie much of the planning of construction processes and construction management research. On the other hand, reactive problem-solving practices are organized and structured in the project's daily practices, and the reactive problem solving becomes instrumental in securing a successful execution when planning is inadequate. The same expectation is found by the agents in the projects, who often have the strong belief that problems can be solved with better planning. The second case exhibits a far more complicated set of practices. It commences as proactive planning, yet is quickly fragmented into elements of planning, production and ad hoc problem-solving. These practices involve an unintended ambiguous learning as the causes of defects remains unclear. The research shows how observed problem-solving practices form a continuum from structured problem-solving activities to a large number of more chaotic and unstructured processes. Both have unintended consequences. Thus, understanding the central role of problem-solving in the realisation of the project is a central point. In addition, not all processes can be planned ex-ante – or be based on the same rationality. The study highlights how routines and experiences can be seen as instrumental in producing and maintaining a certain level of failure, as well as in reducing the extent of failures and defects.

The study's specific contribution primarily concerns understanding the practices that produce and redress failures and defects in a building project. This provides an exceptional opportunity to understand the relationship between the projects' structural conditions, actions of the agents, and unintended consequences. The study shows that a new lens is necessary to understand the causes of failures in the building process as these can seldom be narrowed down to simple causalities or prescriptive models to account for eventualities on site. Planning and problem-solving are both proactive and reactive, yet they are more often forced into the reactive form. Empirical evidence shows that far from all failures have causes that relate to proactive problem solving (planning). It is these asymmetries of agency that are referred to here as dissonant. The practical implications of the study, which follows the project over an extended period of time and goes far deeper and closer to the agents than the company is usually able to accomplish in an internal analysis, cover the individual as well as the project level. This makes it possible for the study to identify why certain corporate structures – external structures in strong structuration – have an impact on the quality of the construction project, while many others do not have the desired effects. This understanding allows the host company to further develop projects and business processes - also strategically. Moreover, insight into the limited role of planning demands the facilitation of a variety of planning and problem-solving approaches, skills and structures across projects and processes. This emphasizes a 'triggering of reflection' in the processes, which can be supported in a number of ways. The emphasis on the unintended consequences of routinized practices also affects the widespread understanding of routines and experiences as being primarily positive in relation to the quality of the processes – and stresses a further need for different competencies and skills across projects.

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