THE ROLE OF PROBLEM SOLVING IN CONSTRUCTION MANAGEMENT PRACTICES

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Quality issues are a topic of continuous interest in the Danish construction industry. Not only can failures and defects be vital to the success of the single project but also the annual profits of the whole company can be put at risk. Moreover quality issues jeopardize the reputation of the entire industry. An Industrial PhD carried out at a large Danish contractor examined how failures and defects are produced and handled in the social practices of construction projects. The study addresses quality issues related to project management and examines the role of problem solving practices in the creation and redressing of failures and defects in construction processes. The theoretical framework is based on theory of structuration and enables the central analysis that includes underlying structures of the actors as well as the processes of structuration. The research project is designed as an abductive research process where theory and empirical data inform each other in iterations. A 15-month ethnographic field study comprised of workplace observations and qualitative interviews was carried out to be able to study the internal structures of the agents and the effect of their general-dispositions regarding quality issues in the decision making and redressing of defects and failures in the processes. The role of problem solving and trouble-shooting is analysed through the well-organized processes of erecting the pre-cast concrete structure and the chaotic processes of constructing the penthouse storey on top of the building. The research highlights reactive and proactive problem solving practices as important for the completion of the construction project. Problem solving practices are however often forced into a reactive problem solving. Implications to the company are to direct the attention not only to the planning but also to facilitate and support the problem-solving and trouble-shooting competencies of projects managers.

Keywords: building defects, problem solving, project management, quality, structuration.

INTRODUCTION

Quality issues in the form of failures and building defect are continuously debated in the Danish construction industry on a national level but also in relation to the specific projects and companies. A summary from the Danish authorities estimated the annual costs of failures in the Danish construction industry to almost 1.7 billion euros - close to ten percent of the total production value in 2004 (DEACA 2004). This correspond a

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study from the Technical University of Denmark (Apelgren *et al.* 2005) and Josephson & Hammarlunds (1996) extensive studies in Sweden. The industry and the former Danish Enterprise and Construction Authority initiated a joint action plan against defects in 2005 and set an ambitious target to reduce the level by 50 % in 2008 (DEACA 2009). An important element was the introduction of a compulsory evaluation system for contractors, developers and consultants in state contracts. In 2009 it was concluded that the extent of defects and failures had decreased in the period 2001-2008 but from 2005 to 2008 the positive trend stalled (EBST, 2009).

The research material originates from an Industrial PhD project conducted from 2006-2010 in cooperation between the university and NCC Construction Denmark – one of the largest contractors in Denmark (Schultz 2012). The specific purpose was to examine how failures and defects are produced and handled in the social practices of construction projects in order to reduce the extent of failures in the building process. Benchmarking data from the company showed that quality issues related to both processes and products amounted to large sums and strategies to reduce this was imposed. Moreover a review of existing knowledge on failures in the industry and within the company revealed a substantial amount of data on the subject both outside and inside the company. However, despite the amount of knowledge on the subject a number of specific problems were produced across the portfolio of projects in the company. This led to the decision that the research should be designed as an in-depth study and focus on how the different knowledge of building defects and other quality structures influenced the processes and actions on the projects. The emphasis was put on the social practices of the project managers; their actions and decision making in general and the role of problem-solving specifically. Hence the paper examines the following question: What are the role of problem solving construction management practices in the creation and redressing of failures and defects in construction processes? By highlighting problem solving, the study has a focus that is often overlooked in construction management research, which often seeks to find prescriptive models to account for eventualities on site. The premise is that failure and defects cannot be seen as isolated incidents, but must be regarded as a correlation between the successful as well as the faulty processes. Failures and defects are moreover considered as consequences of something unexpected or unforeseen.

The paper proceeds with methodology and the theoretical framework of the study. The empirical material is presented in the form of two illustrative cases from a Danish housing project; the well-organized processes of erecting the pre-cast concrete structure and the chaotic processes when constructing the penthouse storey on top of the building. On basis of the method, theory and empirical data the analysis, discussion and conclusion is then presented focussing on the role of the reactive and proactive problem solving practices in the construction processes and how they are often forced into a reactive problem solving.

METHODOLOGY

The research project is designed as a qualitative abductive research process where theory and empirical data inform each other in iterations. The theory is the starting point - an eye-opener - and through an open empirical case-study divergence between theory and empirical findings is discussed and applied through continuous iterations. The study is primarily sociological but elements of an engineer-scientific approach are applied for understanding the rationality of management, the habitus of engineering as well as planning. Based on Alvesson & Sköldbergs (2000) reflexive qualitative

methodology the need for various types of interpretations of the empirical material is acknowledged.

The theoretical framework combines processual elements with elements of stability (structures) via Giddens theory of structuration (e.g. Giddens 1984). A study of preconditions of actions demands for an in-depth study rather than a wider approach so a single-case-study was selected. Single case studies "when compared with quantitative research or multiple case studies is ordinarily judged to be lacking in rigor, comparability, and replicability" (Barzelay 1993). However, it is an extremely valuable method of social science research when used for purposes of analysing how people frame and solve problems (Ibid.). A 15-month ethnographic field study comprised of workplace observations and qualitative interviews was carried out to be able to study the internal structures of the agents and the effect of their general-dispositions regarding quality issues in the decision making and redressing of defects and failures in the processes. As a result of the research design and the rooting of the study in the company the research contributes with an in-depth understanding of the relationship between the structural premises and the actions and decision-making of the project managers and craftsmen on the construction projects.

Empirical material: Reading papers, hanging out, asking questions

The case material stems from a larger turnkey housing project within the company. Corresponding Dingwall in Cicourel (1964) the strategy for gathering insights about the field of research was "reading papers", "hanging out" and "asking questions". In total more than 100 days of ethnographic observations of primarily on-site processes was conducted from September 2007 until autumn 2008. Participant observations and interviews primarily focussed on site management activities and the work tasks of the contractors' project team. Interactions with designers, suppliers, subcontractors, craftsmen as well as functions at the headquarters were also mapped. Numerous qualitative interviews were conducted with relevant actors as well as study visits at the suppliers' facilities. The output consisted of 120 comprehensively written pages of diary, numerous types of documentation, minutes from meetings plus 15 formal interviews.

Limitations are amongst others that not all failures were registered since it was not possible to pursue all parallel activities. Also the massive amount of impressions and data can induce "death by data suffocation" as well as it is difficult to present the nuances of the empirical data and analysis in the form of a conference paper. The possible bias to the investigation as a result of the researcher being employed by the company is included in the analytical reflections. But the Industrial-PhD program setup and the involvement of the research institution should also limit this bias.

STRONG STRUCTURATION THEORY

The theoretical framework is based on Anthony Giddens theory of structuration (e.g. Giddens 1984) which is adapted to the empirical analysis primarily on basis of Rob Stones 'strong structuration project' (Stones 2005). Stones concept of strong structuration is moulding the "dried out" abstract theory of Giddens into an applicable implement for empirical researchers (Larsen 2009). As an abstract grand theory the theory of structuration represents ontology-in-general: "concepts about the very nature of social entities over and beyond any particular empirical manifestation of them in specific social circumstances" (Stones 2005: 7). Supplementary theory on failures and defects as well as the interface and interactions between firm and project (e.g. Winch

1998 and Thuesen 2006) delivers insight of the practical level of the building projects as ontology-in-situ.

The social practice is the mediating term between action and structure and describes the relationship between agent, action and structure in a duality of structure where the three concepts are mutually related. On basis of structures the social practice constitutes individuals as conscious, knowledgeable agents and through "activities agents reproduce the conditions that makes these activities possible" (Giddens 1984: 2). I.e. structures are reproduced or perhaps reinforced or transformed - often unconsciously, which is described as an unintended consequence of the social practices. Structures are thus both the medium and the outcome of the process. Because the actors are knowledgeable, structures are a condition for actions embedded within the agent and moreover structures are media of power. The agents as knowledgeable are expressed through the agents continuous reflexive monitoring of actions either as discursive or practical consciousness (Giddens 1984: 7) but also on an unconscious level (cognition). Structural properties are both constraining and enabling (Giddens 1984: 25) and the unintended consequences introduce the reproductive nature of actions which may as a result of the agents' knowledgeability and reflexivity, or by incident, lead to a change over time.

The duality of structure and agents is in Stones version of structuration theory (Stones 2005) broken into four interlinked – but analytical separated – elements. The distinction is between 1) external structures (relative to the agent in focus), 2) internal (virtual) structures within the agent (separated into a) conjuncturally-specific internal structures and b) general-dispositional structures (resembling habitus to Bourdieu)), 3) active agency and 4) outcomes – as internal or external structures or events. Stones emphasis the notion of conjuncturally-specific internal structures as indispensible to the substantive level of empirical research (Stones 2005: 90). These are not reducible to knowledge gained within immanent interaction, but may well be formed long before they are drawn upon (Stones 2005: 91). Stones' quadripartite methodical structure delivers a tangible analytical framework to the analysis of agent actions. This includes external structures e.g. company procedures, regulation, physical building materials, machinery etc. as well as the agents' internal structures. The latter comprise both the specific knowledge on the different influences related to the task at hand but also the more general agents' disposition e.g. how they prioritize quality of the product to the schedule or the budget.

The assertion is that rational conceptions of failure mechanisms in the building process are not enough in itself since other structures (external or internal) often becomes predominating. Structures do not exist in itself per se; "only in its instantiations in such [social] practices and as memory traces orienting the conduct of knowledgeable human agents" (Giddens 1984: 17 and Kaspersen 2000) i.e. nothing is really a structure unless it affects the activity. This way traditional cause/consequence analysis' often fail to deliver applicable knowledge to the actors since quality focus infrequently structures the construction processes. The presumption is therefore that elements in project cultures and internal structures are essential in understanding the dynamics of problem solving and understanding why substantial catalogues of knowledge on failures rarely affects the decisions on the projects. In the specific situations on-site when the agents have to make a decision or solve a problem they must navigate between a number of different structures and considerations - often conflicting. The understanding of these decision processes seems vital in understanding why some problems are continuously produced across different project.

Moreover it is central to investigate these processes to understand how company structures affect the specific project processes e.g. why some central company quality structures seems to work in some situation while being peripheral in others.

TWO CASES OF PROBLEM SOLVING

The role of problem solving and trouble-shooting is elucidated through two cases from a larger residential construction project; 1) the well-organized processes of erecting the pre-cast concrete structure and 2) the chaotic processes of constructing the penthouse storey on top of the building.

The pre-cast concrete element phase

The first case illustrates a number of "ordinary" small problems and defects in the processes of erecting the precast concrete elements. Subsequently a series of observations from everyday processes around the assembly is included. The carcass structure is based on precast concrete elements and the structural project is modelled in 3D and evaluated by the on-site team as having an unusually high standard. The precast concrete elements are manufactured by three different suppliers and bathroom cabins from a fourth supplier is delivered and mounted with the carcass. The carcass is erected by an in-house team who work as a regular subcontractor on the project. There are a number of failures in the process of erecting the elements and at some point all the different parties are somehow involved in the initiation of a failure in the process. Failures and defects can be related to planning, the structural engineer project, the factories, on-site management as well as execution. However production flaws initiated by the manufacturers in the form of misplaced recesses, joint locks, inserts etc. as well as slanting elements and problems of keeping within the tolerances is common.

The problem solving practices in the pre-cast concrete element phase can be described as very routinized. The following example is the traditional procedure when handling a problem initiated by a supplier. When the production manager on-site becomes aware of a problem (perhaps told by the craftsmen), 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 problems are reported to the manufacturer 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. The procedure secures progress of the production which is considered vital. At some point there are three “finishing gangs” from the different manufacturers present at the site in addition to the original concrete assembly gang. At the completion of the project the parties make a final financial agreement to cover the expenses.

The otherwise mundane assembly story reaches a climax when a construction worker suffers a fatal accident, which puts everyday problems into perspective and test structures and practices to the extreme.

The penthouse storey

As a counterpoint to the concrete element assembly, the planning and construction of the buildings penthouse structure is observed. The processes appear much more unstructured and chaotic. 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 constructed 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. An interior balcony is placed at the rear of the house with a steel railing and a steel cover for the sun. In the processes a number of actors are present; two different carpenters, the concrete contractor, the roofer and a blacksmith among others. Moreover extensive safety work influences the processes. Especially the joints between the sandwich panels and the windows/doors as well as the roof membrane are critical interfaces. So are the interactions between the different actors.

The project managers have no experiences with tightening the building envelope. 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 in small pieces on post-it notes. They also visit the supplier of the steel clad sandwich panels to gain knowledge on how to execute the processes. However as expected a number of problems arise in the execution phase. An initial problem arises when the roofer hires in a subcontractor and the new contractor do not follow the instructions as originally agreed between the project management and the original roofer. However the biggest problems arise when it is discovered that the construction is leaky. Water is detected in several apartments at several occasions. A Blower Door test also reveals that the construction is leaking. Over a period of many months the actors try to solve the problems. Directed by the project managers the actors try to uncover a number of possible solutions as organized as possible. There are repeated adjustments and rework before the construction is considered tight enough to meet the requirements. At the end they succeed in making a tight construction from a number of corrections e.g. additional screws and sealant, additional layers of roofing felt and an extra focus on the quality of the interfaces. However at the end they are still not aware of the actual causes of the ingress of water.

ANALYSIS AND DISCUSSION

The observations from the specific project indicate that the project is the context in which the redressing of failures and defects are structured and reproduced. This despite a focus on activities from the company to enhance the link between business processes and projects. The cases in general illustrate how quality issues pervade the processes in the form of: a) external structures (e.g., corporate structures) and internal structures (relative to the agent), b) the knowledgeable agents (including the importance of routines and reflection), c) in the form of intended and unintended actions (e.g., planning and problem solving) and d) in the form of unintended and undesirable consequences of the processes of structuration.

A key contribution from the study is the understanding of the social practices of problem solving. Another key contribution of the study is the understanding of the unintended consequences of routinized practices; how routines and experiences in addition to helping to reduce the extent of failures and defects, also can be seen as instrumental in producing and maintaining a certain level of failure. Moreover the study show that understanding the causes of failures in the building process demands a wider scope and can seldom be narrowed down to simple causalities or prescriptive models to account for eventualities on site.

The successful project - with a number of problems in the processes

The primary project studied is successful in terms of measures as time and money. Furthermore the social construction of the projects as a success is seen from the articulation of the projects history although an occupational injury leading to the death

of a craftsman is somewhat damaging this picture. Factors as competencies and collaboration across the value chain, the project being very carefully worked out and a consistent project team throughout the design and execution phase is pointed out as important to this success. Despite of this the empirical data shows that a wide range of problems is present throughout the on-site production phase. Most of the failures can be described as minor problems leading only to a limited reflection and narrow actions to redress the problems. Only one problem - the fatal injury – can be said to have a direct impact on future processes outside of the project.

The social practices of problem solving

Failures are detected when the reflection of one of the involved actors is somehow triggered by the quality of either the product - e.g. the quality of the panels - or the processes. Their reflexive monitoring perceives that something is not as expected. The social practices of problem solving in the case of erecting the pre-cast concrete elements can be described as routinized. Moreover it is almost expected that the elements are flawed. In this case the production managers have a very structured routinized process of problem solving that is supported by corporate structures in the form of formalized spread sheets and procedures to address the problems related to the suppliers. It is also included in the contacts and thereby closely linked to the responsibilities of the actors. This way it is formalized both in respect to the external and internal structures relative to the agents which is a consequence of highly standardized processes; the processes and product resembles many other traditional housing projects in the company.

In the case of the penthouse it is by chance that the leak is discovered at all - it starts to rain! Causes can be related to both a lack of communication, skills, knowledge and execution. Nevertheless at the end they solve a problem without knowing the root causes. The processes of problem solving can be described as highly chaotic in spite of the projects managers attempt to organize the processes. This can be seen as a consequence of both the processes as well as the final product being relatively unique and unstandardized.

Problem solving is a repeated activity pervading most construction processes and can both be considered as social practices but also as the project staffs' general-dispositi-ons (or habitus); as internal agent-related values. The latter becomes relevant when considering how the agents prioritize quality to other dominant structures e.g. the earnings/budget, time/schedule and/or responsibility/contracts. The social practices are both structured by actors' dispositions, their context-specific knowledge (internal structure) and sometimes also supported by external structures.

A continuum of problem-solving practices with unintended consequences

The cases illustrates two types of problem-solving practices; routinized and chaotic However, omitted empirical material reveals types of problem solving that combines elements of both. Hereby the two cases represent the extremes of a spectrum forming a continuum from; a) structured problem-solving activities to b) a large number of more chaotic and unstructured processes. Both "extremes" have different starting points and introduce a number of unintended consequences. The well-structured problem-solving practices introduce problem solving as a relatively pragmatic practice that does not address the root causes of the failures and defects. Hereby the on-site problem-solving strategy does not handle the underlying causal structures but only solve the manifested problems here-and-now. This is illustrated by the procedures where discussions on responsibility are postponed until later and eventually

transformed to a bargaining not addressing the causes at all. 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 - reproduces 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 organizational learning. The extensive observations of the agents in the construction project this way shows some examples of firmly established hard-core routines and practices at the construction project, where agents reproduce practices that produce failures and defects; failures and defects are thus unacknowledged conditions of the actions.

The relationship between planning and problem solving

The research highlights the relationship between planning and problem solving. Design, engineering, planning and problem solving can all be considered as problem-solving practices. The parts that relate to the correction of the defects and failures often take the form of reactive problem solving, while the other activities can be described as proactive problem solving. The reactive problem-solving practices are highlighted as important for the realization of the construction project and as a vital element to ensure that planning and design is achieved in the finished project and that the project meets the clients' demands. The problem-solving practices are often forced into a reactive problem solving. Moreover the cases show that far from all failures can be traced back to the design, engineering or planning (the proactive problem-solving practices). The on-site staff and construction managers are often uncertain and vacillate about the premises, causes and consequences of their choices and actions in their problem-solving practices. The problem-solving activities are organized and structured in practice but at the same time the importance of these problem-solving activities can be seen as neglected or overseen in many of the planning paradigms underlying most of the planning of the construction processes.

Structures in problem solving

The project staffs draws on a varied, nuanced network of abstract structures. Corporate structures are often omitted or used in a different way than originally intended and specifically "quality structures" (that is both internal as well as external relative to the agent) often proves peripheral. There is a contrast between process engineering incentives and economic incentives; "economy" and partly "progress" (in the form of scheduling) becomes dominant structures, while quality is considered a lower priority. "Quality" and "responsibility" as structures are to a 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 as time and money become predominating and among other structures also previous individual or project related experiences can be structurating. These experiences are highly dominated by individual experiences or experiences in the project network and seldom based on organizational experiences. Often the structures must create a direct sense of value to the individual or the project. This selection is also based on the experiences of the actors and the project network and to a great extent it can be seen as a social construction. This highly affects the selection and deselection of structures at hand. Moreover direct procedures, orders or commands can be structurating. In contrast or collaboration with incentive structures and rewards it creates a tense space to manoeuvre for the actors. These characteristics

can be seen as elements of project cultures that can be described as highly resistant to outside interference.

Knowledgeable agents

The knowledgeable agents are very "visible" in the processes of problem solving with different prerequisites to achieve their results. The results can best be described as mixed as it can be seen, that in both cases failures and defects arises.

The processes of problem solving in the penthouse case become very dependent on the agents' internal structures since it is unsupported by corporate structures. Moreover the agents do very little to access knowledge in the company environment outside the project. In the precast concrete panels' project a dedicated engineer is assigned for the project engineering which is not the case in the penthouse project. This way there is a lack of a 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 different subcontractors as well as different materials it is a different set of knowledge and competencies that is required than what is the case of the precast concrete project.

Cultivate the reflective practices of the project managers

The complex problem solving processes in the tightening of the penthouse shows us that different sets of knowledge and competencies are required across the project. A solution could be to further facilitate and support the problem-solving and trouble-shooting competencies of projects managers; to create structures and practices that cultivate the reflective practices of the project managers. Moreover competencies on the interfaces both between actors, materials and processes could be further strengthened. These types of competencies could probably advantageously be in-house competencies of the contractor depending on the situation.

CONCLUSIONS

The paper examines the role of problem solving practices in the creation and redressing of failures and defects in construction processes. The significance of the reactive problem solving is considered neglected in the planning paradigms that underlie much of the planning of construction processes. On the other hand reactive problem solving practices are organized and structured in the project's daily practices and the reactive problem solving becomes an instrumental part to bridge the gap between planning and execution and secure a successful execution. The same expectation is seen on the level of the agents who often have a fierce belief that problems can be solved with better planning.

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. The well-structured problem-solving practices introduce problem solving as a relatively pragmatic practice that does not address the causes of the failures and defects. At the other end of the spectrum the on-site staffs reproduces themselves as strong problem solvers which is a hindrance to organizational learning.

Planning and problem solving are both characterized by the identification and redressing/handling of a problem and are hence described as proactive and reactive problem solving. In various ways reactive problem solving creates a link between some more or less coherent design processes (planning) and execution processes.

Problem-solving practices in the project are often forced into a reactive problem solving. Empirical evidence show that far from all failures can be traced back to the proactive problem solving (planning). Moreover, the study shows that understanding the causes of failures in the building process demands a wider scope and can seldom be narrowed down to simple causalities or prescriptive models to account for eventualities on site.

Implications are focussed on the company structures and processes of the contractor as a consequence of the research rooting in the company. Implications are to direct attention not only to the planning but also to facilitate and support the problem-solving and trouble-shooting competencies of projects managers; to create structures and practices that further cultivate the reflexive practices. Moreover it is central to ensure that experiences and solutions of the local problem solving becomes available to the entire company; to facilitate proper structures and practices for knowledge sharing. Perhaps a trivial point - but highly relevant.

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