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Learning from Failures in Operations

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Abstract

This paper discusses failures and quality in operations in design and production of buildings. The importance of human action, interpretations and interactions in tackling complexity, fragmentation and disturbances in the building industry is underlined. Building processes encompass requisite parallelism and fragmentation due to their predominantly quantitative complexity. It is suggested that a number of critical junctions occur in these processes and that obtaining quality and avoiding failures quite often requires a series of competent and situational operation management actions.

An empirical study of failures and their causes was carried out in the spring of 2004. The observation period was three month covering the assembly phase. In this period we observed 160 failures equal to a calculated cost of 80.800 euro and 8% of the production costs. However only 7-8 % end up as impact on the final product. The analysis showed that, among others, design review, project review, commencing and finalizing operations turned out to be critical junctions in the control of failures.

Practical implications and improvements are discussed. The focus on critical junctions, points to supply chain management, lean construction and operational innovation in the site organisation as possible elements. Moreover the importance of flexible daily coordination is underlined.

Keywords: quality, failures, review

1. Introduction

2005 can be a turning point in Danish Construction. The obligatory evaluation system in state contracts will be inforced by July 2005 and The Benchmark Centre for the Danish Construction Sector will develop an important database of performance indicators that can be extremely instrumental in creating operational innovation and improved quality, where the data shows its needed (Byggeriets Evalueringscenter 2005). Poor quality has been a long-term feature and debate in Danish construction. Especially the final quality vis-à-vis the client has been in focus. The last wave of reforms from the state as a response to this commenced in 2000 (EFS 2000). The focus of the paper is on failures in operations. Failures and productivity is linked, since failures lead to increased use of materials and resources, and as it will appear the main preoccupation here is with lowered productivity.

2. Method

The study behind the paper (Apelgren et al 2005), covers a period of three months. An observer followed the daily execution of work at a building site, which was in an installation phase (roughly from 25 to 70% finished in the period observed). In total there was 38 observation days, sampling 1 to 10 failures per day and 4 in average. Registering 160 failures and subsequently making a series of interviews, carrying out an analysis of the causes behind the failures.

Each failure has been analysed looking for proximal as well as distal causes either in organisation, technology or human resources. Moreover a calculation of the material and man-hour costs was carried out for each failure in cooperation with the operation management of the building project. The single failure analysis was followed by a thematic cross-failure analysis. In this paper some illustrative cases of the process of a failure is chosen to illustrate the problems around the critical junctions in assuring quality.

The strength of the method is that it gave a substantial material covering a wide range of causes and types of failures. However not all failures in the period were registered since it was not possible to follow all parallel activities on the building site (Josephsson et al 1996 has a similar result). Moreover failures could be characteristically different in different phases of the building process, a concern backed up by other studies made in the early phase (Apelgren et al 2003) and the late phase (Andersen et al 2005) of construction of a building.

3. Construction operations

As a project based production system, construction is not entirely producing "one of a kind", but at least a low volume with high variety (Slack et al 2004). Operational processes in construction undergo a characteristic transformation from being predominantly a production of an immaterial professional service in the design phase (design documentation), into being a production of a combination of a physical and immaterial product (a building and the related information on its operation). A widespread understanding of the processes also within practical construction draws on operational analysis and systems theory, relying on the classical transformations model "input- transformation- output", picturing operations as a succession of transformative tasks (Koch 2004). The many micro operations in parallel is however a central characteristic of construction operations, both during design and production of a building. Bertelsen (2002) therefore describe construction as chaos. He distinguishes between "chaos in the small" and "chaos in the big". "Chaos-in the-small" refers to the common situation in construction, where the short-term developments, like acts by different parties, cannot be accurately predicted. In turn, "chaos-in-the-large" means a situation where the progress of the whole project cannot be predicted. Bertelsen et al (2003) argues that chaos-in-the-small may speedily turn into chaos-in-the-large if not observed, understood and kept under control. Central for the understanding of building processes is moreover the double variability (Duc 2002, Carassus 2002). Double variability is the combination of external variability due to heterogeneity of products and markets and the internal variability refers to handling live work with its flux in space and time. The external variability creates complexity through unclear and emergent demands from the client and the characteristic fragmentation amongst companies in the industry; architects, technical advisor and contractors. The internal variability can be seen as occurring as a result of *quantitative complexity*; the products and process consists of a very large number of components and subsystems that need to be produced and assembled. Moreover designs of details are usually occurring overlapping with the execution period. This in total creates multiple and parallel processes. Parallel operations are at the same time interdependent and can therefore be expected to interrupt and disturb each other. It can be conceptualized as building processes encompass requisite parallelism and fragmentation due to their predominantly quantitative complexity. Construction processes therefore occur fragmented, interwoven, and with strong interdependencies. The operations share physical space, share abstract space (site management, negotiation and coordination) and the conditions are dynamically transformed over time. Interruptions are planned and unplanned.

4. Avoiding failures and raising quality

Quality is a central performance parameter for operations, and Galloway (1998) proposes to distinguish between design, conformance and operational quality. Design quality relates to meeting the customers needs and will not be discussed further here, since it in the present case setting coincide with conformance quality. Conformance quality is the extent to which the operation systems deliver products and/or services that meet specification (Crosby 1980, Galloway 1998, Dale 2003). Finally operational quality encompasses the "right first time" and free of errors approaches in creating uniform and dependable work practices (Deming 1986, Dale 2003). In various settings however conformance and operational quality proves to be difficult to define, and also become subject to massive interpretations by various actors (Strange 2005). In the present context of construction processes the interaction between trades, companies and professions imply that quality issues are continually negotiated and contested. A direct implication of this understanding is moreover that, what constitute a failure is equally difficult to define. In a construction setting operation processes, input and output are rarely fully described in a way which makes it meaningful to understand failures as merely deviations from defined quality. We therefore take an interpretative position using the term "stumbling stones" defined as " all the phenomena that hinders the actor in doing his work right the first time" (Kjeldsen 1994). Using this definition methodologically means to adopt a "follow the actors" approach. Causes behind failures have been studied by a number of scholars within construction (Josephsson & Hammarlund 1996, Love & Li 2000 a.o.). Josephsson thus finds a pattern of widespread reasons dispersed over the entire set of actors active in a building projects; designers, building components suppliers, operation managers, craftsmen and other employees. Moreover Josephsson et al. finds that a majority of failures occurs because of what appears to be lack of motivation, but which at a closer look turns out to be the individuals that cannot cope with the many dimensions of information and the attention needed. Only as an extreme exception did deliberate neglect occur.

4.1 Actions taken in Danish Construction Industry

The first wave of debate and subsequent action occurred in the 80ties. In 1986 an order on quality was issued covering public financed and subsidized building activities (Bang et al. 2001). This installed formal procedures and documentation in design and production. A second element was uniform liability periods in the state supported building activities. A third element was the establishment of the building defects fund, which is an insurance pool covering defects found after production(Bang et al 2001) and which commenced registering the amount and type of defects and thereby became an important indicator of overall quality in Danish construction. These initiatives were followed by installation of industrial norms and guidelines (such as project review guidelines from the association of consulting engineers 1988). A number of construction companies moreover took quality management initiatives following the ISO 9000 series (Bang et al 2001).

The second wave of debate and reform occurred in 2000 initiated by the government (EFS 2000). The critique on poor quality was built on the statistics from the building defects fund, showing a high level of end product quality problems, and accompanied by other critiques of non-transparent pricing and too high costs. Again public financed and subsidized building activities are used as lever for the rest of the industry. Quality regulations was renewed and improved (By og boligministeriet 2001). The most important initiative is the Benchmark Centre for the Danish Construction Sector. The state will only accept enterprises, which have been evaluated three times at the benchmark center, as potential suppliers after first of July 2005. This goes even for the pre qualification for a call for tender. By April 2005, 600 evaluation cases are active and the database of obtained performance indicators can be expected to give a very strong insight in quality levels in Danish Construction. As a consequence of these developments a series of "quality institutions" has been embedded in building processes in a Danish context. They can be understood, as the pinpointing of a number of critical junctions, who are assumed will assure the production of design, conformance and operational quality. The following activities are part of the critical junctions: Design review, project review, Auditing plans, begin and end controls (relating to operation processes), 1 year audit and 5 year audit (post construction). Even though there have been signs of improved quality in the sector, the debate recommenced in 2004, with a new public initiative, that based on a small literature study claimed that failures cost 1,6 billions euro per year (SBI 2004). One can therefore speculate that a third wave of initiatives possibly based on the Benchmarks centre results will emerge the coming years.

5. Case

The project investigated is a medium size building project. The cost budget was set at 4,4 million Euros, encompassing a design budget of about 400.000 Euros. The aim of the project was to built 27 apartments, in six separate buildings. The client and the main contractor are identical, and the contractor used in house designers and craftsmen for three design areas out of five and six out of 17 subcontracts within production. The project was equipped with a four-man project management group. In sum these characteristics makes it an average building project in terms of organisation and balance between in-house and sourced resources.

5.1 Main results

160 failures were sampled during the three-month observation period, which equal costs of 8% of the production sum. The cross-case analyses showed a mixture of causes in each case and it was not possible to assign single causes to the single cases. More specifically 14 % of the failures had exclusively distal causes, and 19 % exclusively proximal causes whereas 67% had mixtures of those. In contrast to Josephsson & Hammarlund we found it difficult to place the cause with one actor. It is in the vast majority of our cases a series of "subsequent" actors as well as one originator that is involved in the generation of the failure on the site. It was analysed whether the registered failures were predictable or non predictable on the basis of existing knowledge on the site. It was found that 56% of the failures was predictable. There is thus a large room for improvement. Of the total failures the organisational causes were the most prevalent. Of the organisational, the following causes scored the highest. Problems with communication and cooperation 61%, design activities 45%, production planning and control 42%, project review meeting 36%, production work 34%, process and product control 29%, weather and theft 20% and access to skilled workforce 15%. Although organisational factors played the most important role, we found failures related to all kinds of interaction between the actors in the project. It involves formal organisational elements such as meetings as well as informal interaction. Communication and cooperation is a central activity in a multi actor project and it could be added speculatively that the found level of problems is less alarming since it should compared to the amount of communication and cooperation carried out in the project. Apart from the organisational factors, the analysis covered technological and individual factors as well. The technological failures relates to 37% of the observed failures. They relate to issues like purchasing of material, equipment, which had not been properly cleaned and features of the product like a too broad plinth. The individual factors were found at 40% of the failures. They relate to competence (24%), erroneous acts (18%), avoided acts (11%) and hindrance due to limited resources(53%). It follows indirectly from these figures that focusing on the individual would have less of an impacts in terms of improvement.

After the failures occurred the actors put various measures in place to repair the damage and the analysis shows that only 7-8% of the failures affected the final quality. The consequences and costs involved thus relate to manhours and materials used to obtain an acceptable final result. The loosers in this game are the participating companies how obtain less surplus.

5.2 The critical junctions: Some illustrative examples

The carpenter mounting gypsum plates in a litter room, designed for garbage containers, found a difference of about 10 cm between the precast concrete wall and the gypsum wall. A check of the drawings showed that both the gypsum wall and the concrete wall were placed according to specifications. It is revealed that the discrepancy occurs as a difference between the architect material and the building physics material. Interviews with the architect and the engineer does not clarify where the failure originates, since the architect claims it was an unrevealed failure, whereas the engineer claims that a change of design have not been recorded properly. The architect design a new solution for the litter room, covered the detail with zink, changing the size of the garbage container and suggesting moving the door to give space. The case suggests that cross-disciplinary design review have been suboptimal. There are several of these failures in the sample

The electrician working with finalizing installations in the kitchen finds a small part of a wall, which has fallen down in a niche. It turns out to be a symptom of the kitchen assembly where the craftsman have drilled through a wall and has harmed a cable and a wall. The kitchen assembly did not require such a deep hole, since the screw in question did not have to carry a heavy load. The initial control as well of the end control of work at the building site, shows a characteristic pattern in the sample. The cases found demonstrate that end control have been insufficient, leading to that initial control reveals failures. In this case the failure was reported, but in the next it was not.

A painter painting a concrete wall finds a hole and decides to cover it with a clothlike material. Another painting company is later hired to do supplementary painting as is also asked to check quality of existing work. When checking the wall in question the cloth solution is revealed. The site management decides to fill out with cement and repaint.

6. Discussion

The case examples are chosen to illustrate the general finding that design and project review as well as quality checks during production could be improved considerably in the building project investigated. These events are critical junctions in the process of keeping up quality.

As noted above, it is in the vast majority of our case a series of “subsequent” actors as well as one originator that is involved in the generation of the failure on the site. Responsibility and needed action therefore lie on the shoulders of a whole series of actors in the process.

In our view quality as an activity should be integral in operations and operations management. Following from the analyses of cases our suggestions for improvements cover not only quality issues but also other issues. Our main suggestion for improvements cover design, project review activities, production planning, boundaries between contractors, communication and cooperation and competencies and experience (Richter & Apelgren 2005). The final quality of the product for the end user was less harmed and it was the efficiency of and lowered productivity of the contracting firms, which was our main concern. Following

the critical junctions we propose the following: *design reviews* needs to be prioritized. Building design occurs under time pressure and as parallel processes. Nevertheless a few extra man-hours for collision control and the other review activities are likely to be beneficial. The *project review activities* across designers and with contractors are in the present investigation carried out in an almost symbolic way. Our analysis shows that both preparation to the meetings and structured written minutes could improve the results of the meetings. The structure of the minutes should encompass pinpointing who is responsible for subsequent action. There are some positive side effects since the participating contractors develop an in-depth understanding of the project demands and can do the manning of the project more precise. The boundaries between contractors give problems. There are different interpretations of *demands of finished work* between the contractors and their employees. Therefore precise demands in the project material are crucial and it is not enough to list standards, which is often seen. The potential for improvement of *production planning and control* is also important. Lean construction methods, in particular last planner, were sought introduced in the case, but in a partial manner that makes evaluation of the impact impossible. The human and coordination element of building processes is largely left untouched by lean methods. It is suggested to introduce at least two more dimensions of operational management at the site than the ones offered in for example lean construction; human resource issues (coordination, knowledge and communication) and site management issues. The field studies show a vast amount of interruptions in operational managers work at the building site Koch (2004)
Moreover, this and other cases (Andersen & Hoffmann 2005, Apelgren & Holten Nielsen 2003) suggests that day to day informal management activities are as important as weekly meeting of foreman and others.

7. Conclusion and implications

The study has shown that the main focus in improvements can be on operational quality, developing procedures that prevent reworking. The focus on critical junctions in producing quality points to not only a need to improve the quality institutions, but also at supply chain management, lean construction and operational innovation in the site organisation as possible elements of a improved operations that assure and deliver quality. It is suggested that operations should be understood not only as quantitatively complex and fragmented but also as interpreted and negotiated between the participating actors. Seen in this perspective learning is difficult to control, and although it occurs that does not imply that learning is developing operational performance.

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