# NEGOTIATING AND KNOWING BUILT QUALITY

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This paper focus on the world of creative activity underlying structural designs and progress plans. In the world of practice, "knowing" is embodied in efforts as much as a cognitive precondition for efforts. Each worker and team have to cope with complex situations and solutions where no single contributor has full overview, neither of current and future production operations nor of current nor future functionality. Successfully creating micro-conditions for efficient operations and high quality outcomes hinges on continuous monitoring, dialogue and negotiations. Essentially, production work is an ongoing combinatorial activity, often it is a struggle against stubborn resistance offered by both people and materials. The analysis is based on original ethnographic data and shows that dealing with inaccuracies, errors and contradictions is at the very core of the production effort. Understanding better how high quality operational outcomes are achieved by processing deviations through integrative and complexity-reducing efforts, more is also understood about the potentials and limitations of formal quality systems.

Keywords: building, complexity, integration, practice, production, quality

## INTRODUCTION

Building is often conceived of as essentially a straightforward assembly process. However, the simple linearity of operations that we could imagine being brought forth by freezing designs, sorting out sequential dependencies up-front, and diligently carrying out one operation at the time, cannot be realized because this would disregard even the most basic of economic considerations. Real-life construction and building must all the time cope with unforgiving economic realities. The pressures for economic efficiency transforms the production of built objects into a complex discontinuous and non-linear process where the great heterogeneity of elements, dependencies of operations, and the urgency of avoiding waste becomes the raisons d'être both for a professionalized construction project management, and a considerable portfolio of project management tools and techniques.

This complex process is also the principle reason why administrative quality management systems themselves have to be complex (Ashby, 1958; Bertalanffy 1971). The fundamental thinking regarding quality control, however, tends to be uniform across complex and non-complex contexts. Generally, two issues are considered: First, the safeguarding that those carrying out operations have the necessary skills and knowledge and are placed in work situations wherein their skills and knowledge can be put to use in effective and economical ways (Ballard and Howell, 2003; Bølviken and Aslesen 2017). Second that a proper quality control

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system is in place. Generally, this is taken to mean that output from operations is monitored and that deviations from planned outcomes, formal quality standards and accepted norms are identified and corrected (Winch, 2010, Deming 1982).

There is a vast literature on quality within and outside the construction management research field. Built quality is an integral objective of well-known approaches to process improvement in building and construction, such as integrated project delivery, lean construction and the use of advanced building information models. Standard courses in project management deal with quality systems as a matter of course, and the International Standards Organization has been developing a systematic conceptual framework for quality management.

These approaches tend to consider insufficient built quality as deviations that should have been avoided if only work throughout the stages of a construction project had been carried out diligently and in line with accepted standards, norms and practices. This paper advances what some would say is a contrarian and slightly provocative proposal: Rather than seeing errors and contradictions during building and in the resulting built objects as unfortunate and avoidable exceptions; errors and contradictions are instead considered a basic and unavoidable part of the production processes giving form and shape to any built object. Dealing with imperfections is at the heart of what project based production of built objects is about.

The focus here is on the "sharp end" of project based production of the built environment: the actual building work on-site. One question guide the discussion in this paper, regarding built quality: If errors, deviations and contradictions in project based production of the built environment cannot be explained simply by pointing to human inability or unwillingness to carry out what is suggested in even the best pre-made designs and progress plans, then how can we account for such deviations?

## THEORETICAL FRAMEWORK

In the period after the publication of seminal papers by Winch (1998) and Slaughter (1998, 2000) significant new contributions have been added to the literature on construction innovation, as well as on the general production process prevalent in modern construction. Edited books have added to our knowledge of innovation, such as Akintoye *et al.*, 2012 and Orstavik *et al.*, 2015. The particular challenge of complexity in construction has been recognized by many authors (Baccarini, 1996; Brady and Davies, 2014; Cicmil and Marshall, 2005; Gidado, 1996; Hobday, 1998). Often, however, complexity is seen as an unfortunate side effect, for example of political ambition and outside pressures (Flyvebjerg *et al.*, 2003).

Theoretical arguments can be made, that efforts to work complexity out of systems are doomed. Complexity is integral to and unavoidable in large, dynamic systems (Ashby, 1958; Luhmann, 1984). Defining a system generically as a set of related elements (Bertalanffy, 1971), the claim that both a built object as well as the construction project as such are composite systems-of-systems, should be uncontroversial. Both the construction project itself and the built object are man-made associations of artefacts thought of and designed as systems. Unsurprisingly, what is found by observing on-going construction projects in ethnographic field work is that production is carried out by work teams that are dedicated to creating each of the manifold sub-systems (such as the concrete body of the building, and the electrical system), or parts of such systems. These sub-systems either make up the overall built object, or make up temporary arrangements that are needed in the ongoing production effort (such as scaffolding).

Complexity is a property of systems by which feedbacks and incomplete integration produces non-linearity, unpredictability and risk (Nicolis and Prigogine, 1989). As Luhmann and others have made clear, even if complexity cannot be avoided in large systems, it can be managed. Managing and modulating complexity has the obvious purpose in construction of avoiding catastrophic unforeseeable events, but also to avoid disconnections in operations that seriously hamper production flows (Ashby, 1958; Luhmann, 1984, 2000; Winch, 2010).

By being worked upon and structured, complexity can become more innocuous what regards the essential functioning of a system. Many examples of this is found in safety work in construction, where effects of unintended and unforeseen events have to be mitigated before they occur. The use of personal fall arrest systems is an example of complexity management efforts in this sense.

In the case of the many systems making up the built object, containing complexity entails at least two different efforts: First, reducing complexity by making systems and sub-systems smaller; for instance by standardizing and by reducing the overall number of elements. Second, containing complexity by structuring it. An example of this is when procedural guidelines are implemented to limit the range of variation when concrete is poured on-site. Another example is when learning by doing leads to bespoke designs or procedures implemented ad-hoc during the production process. A third example is modularization, as when prefabricated bathroom cabins are used in a new-build project.

The hypothesis that is explored in this paper is that there is significant overlap between controlling built quality and managing complexity. The interest here is not quality on the level of supplied materials, components and subsystems. The fact that hardwood flooring, tiles, ventilation systems, kitchen furniture, lifts and elevators, and so on and so forth, can be bought in diverse qualities is not considered here. Focus is instead on the production work; on the assembly process going on on-site. The argument will be made that it is in their active reigning in complexity that craftsmen and workers realize the quality of a built object.

## METHODS

Background data for the analysis in this paper have been gathered in ongoing construction on-site, in collaboration with a large Norwegian constructor (Constructor V). Case study research was carried out in two construction projects in the years 2008 to 2012, here called Project M and Project S. Descriptive case-study methods were employed (Eisenhardt, 1989; Yin, 1994). The core data for the subsequent analysis, however, were gathered in the more recent Project K, by way of an ethnographic study employing standard fieldwork methods (Bernard, 2002; Miles, Huberman, and Saldana, 2013). Projects M, S and K all produced a combination of residential buildings with some commercial space at the ground floor and underground garages. Constructions were with a basic structure of poured concrete, internal dividing walls made with steel beams and gypsum boards, and outer shells made with standard timber frames, with various prefabricated materials making up the outer surfaces. Roofs were generally flat and fitted with waterproof membranes. These are typical characteristics of many current building projects in urban areas in Norway, and most likely common also in the rest of Europe. Indeed, it was found in all the projects studied, that suppliers of materials, components and equipment generally were affiliates of international businesses, and products and standards employed reflect standards and regulations worked out on the European and international level.

For the argument of the present paper, findings from project M and S function as a background for the more intensive field work carried out in project K. The general goal of the case studies and the ethnographic field work was to lay bare the systemic nature of the construction projects and the outcomes from project based construction production.

During the fieldwork in Project K, data were gathered both outside, in the construction site among the workers there, and in the offices in which project management was located. Workers were provided with space for eating and resting, and workers were observed and interviewed also in this location. Key people were interviewed in sessions lasting between 1, 5 and to hours and all these interviews were recorded and transcribed. A significant number of meetings of various kinds taking place in the offices on-site were attended, and all of these were recorded, but only one of these have so far been transcribed verbatim. Site visits were carried out every week, often several times during a day and a week. In these visits the researcher observed, had conversations with single people or groups, and pictures were taken, sometimes in the form of short videos. These visits were all logged, and notes taken on observations and the content of conversations.

Through site visits and observation not least of work processes, a nuanced and deep understanding was gained of what was taking place in the building site, both in the production and in the administrative function of the site operations. With the data gathered in the fieldwork in Project K, data was produced for two specific analyses reported in the following. One in which the organization of the project was mapped, and the systemic nature of activities scrutinized. A second analysis was made possible having access to internal meeting minutes from the weekly meetings where foremen, team leaders and other project management representatives discussed ongoing and future work operations, and corresponding needs for managerial action. A particular interview was carried out as a walk-through of a researcher-generated log of critical tasks and observed discrepancies, based on a near-complete collection of meeting minutes from Contractor V that were distributed after meetings during the fieldwork period (about 7 months). In this interview, the significance of discrepancies and contradictions were investigated, reasons for their emergence reflected on, and the ways chosen to mitigate them described and discussed.

## Project K Activities and Outputs

In this section, findings regarding the organization of production on-site will be related in terms of activity areas (division of labour) and work groups (that we characterize as activity systems).

*Division of labour and the nature of outputs*
Researching ongoing production work by way of non-participant observation in the ethnographic fieldwork, it was found that the fundamental principle of the division of labour in project K was systemic. This finding was corroborated by observations of near identical work organization carried out during the case study research carried out in projects M and S. The built objects are created by distinct work teams that are each responsible for creating specific sub-systems of the built object. In project K, the contractors and suppliers involved nearly always had their own dedicated work teams

doing on-site assembly work. This is shown in Table 1, where the right half of the table is the continuation of the left half of the table. There are 3 columns: the contractor or supplier is identified by an acronym (FA, V, etc.) in column 1. Most of the acronyms from column 1 reappear in column 3, specifying what firm actually carried out the relevant on-site work. The middle column is used to explain the area of activity in general.

*Table 1: Division of labour*

| Contractor or supplier | Activity area | On-site assembly by | Contractor or supplier | Activity area | On-site assembly by |
|---|---|---|---|---|---|
| Machine Contractor (FA) | Foundation | FA | Door supplier (SW) | Doors | V |
| Main Contractor (V) | Concrete | V | Membrane specialist (IS) | Roof covering | IS |
| Formwork supplier (RA) | Concrete | V | Electrical contractor (P) | Electrical system | P |
| Scaffolding supplier (RA) | Various | RA | Plumbing contractor (T) | Water | T |
| Manpower Services (AD) | Concrete | AD | Sprinkler subcontractor (S) | Sprinkler | S and T |
| Steel supplier (NS) | Concrete | V | Ventilation company (BR) | Air circulation | BR |
| Steel producer (SS) | Concrete | V and SS | Plasterboard builder (GP) | Internal walls | GP |
| Various suppliers | Concrete | V | Masonry contractor (MM) | Façade, wet room | MM |
| Main Contractor (V) | Timber | V | Tinsmith company (VK) | Tinsmith work | VK |
| Sub-contractor (MB) | Timber | MB | Painting contractor (BU) | Surfaces | BU |
| Timber supplier (SAG) | Timber | V and MB | Flow-floor supplier (AB) | Floors | AB |
| Various suppliers | Timber | V and MB | Flooring supplier (BA) | Hardwood flooring | BA |
| Window supplier (LI) | Windows | V | Kitchen supplier (HT) | Furniture | HT |
| Door supplier (SW) | Internal doors | V | Lift supplier (SC) | Lifts | SC |

A key point brought forth from this analysis of specific domains and work operations is that all outputs on-site have systemic properties. Workers relate elements into specific subsystems. Importantly, not only technical subcontractors (plumbing, electrical, ventilation, lifts) produce systems, but that also, for example, the concrete structures, the internal walls, facades and surfacing and foundations have systemic properties: they are designed and created as sets of functionally related elements. A few firms act as pure suppliers of materials, tools, etc. Often, it is the project owner, Contractor K that receives these deliveries and use them in their own work on-site.

Another key finding is that work teams are social groups, often well integrated into collectives marked by high levels of trust and solidarity, but still consisting of people with specialized skills and knowledge. The groups form activity systems, in the sense that the skilled group members deal with specific materials and tools that they themselves generally bring to the site and know well how to handle. The work groups have their own professional informal norms and formal rules pertaining to their specific domains. Generally, the systems that are created in one activity system (or group) are made from prefabricated, mass produced standard parts, with known properties. There are often well-defined methods for connecting elements into complete, bespoke systems tailored to the particular built object in which it is being created.

Being made from standardized parts and made into well-tried complete systems architectures, there are generally few surprises in the functioning of the completed systems. Provided, of course, that assembly work has been carried out adequately. This, however, is not always a given. Errors and sub-standard assembly in this sense, is always a possibility, and can create functional failures and dysfunctions when the completed system is made operative. For this reason, administrative quality assurance systems are common. These are in part devised, implemented and followed up by the work-teams themselves. Some oversight, however, is being effected by high level administration in Contractor V, by way of corporate safety and quality systems imposed on the project top down and via project management. These are generally based on controls effected by management, in weekly inspections or in connection with completion of specific task; when what has been created is “taken over” and accepted as completed by the contractor.

*Communication, negotiations and production flow*

Even though the systems based nature of output does allow for work group independence to some extent in day to day operations, project-based production does not allow teams to work independently over longer periods. In varying ways and degrees, teams depend on other teams in their operational activities. The basic reasons are two: The first is that sub-systems are entangled in the built object; either because space is scarce and physical contact (or near-contact) unavoidable; or because there is actual interpenetration between diverse sub-systems, as when electrical power and/or electronic automation functions are applied to water systems. The second reason is that there are numerous dependencies between operations and, hence, between work groups.

There is, as information in Table 1 serves to highlight, much variation in terms of work-involvement times on-site. Some suppliers are staying there only briefly, for example to unload goods, while other firms remain as service providers for long periods, even for the entire production period. For example; in project K, the technical subcontractors P and T stay on-site nearly as long as Contractor V does. For such reasons, some work teams are much more closely integrated into the project organization, than other firms are. They take part in intra-project communication and ongoing negotiations (in formal, scheduled meetings as well as in informal talk) regarding issues such as production coordination and flow. Still, all work teams on the site have to communicate with project management and often with other teams directly, to handle practical issues that are not made explicit in any structural design drawing or progress plans.

Coordination is a technical issue concerning the actual building process, but it is also a timing issue concerning many other issues than the technical. For example, remuneration in Project K is generally based on production work done and documented. The effect of this is that work groups have a primary interest in production flow - as experienced by own team members. Unpaid waiting caused by others is detested, while there is notable motivation for high-intensity work in the cases when project management accepts piecework pay.

## Complexity in Building

The observations done in projects S, M and K indicate that well-assembled subsystems of the built object generally has limited complexity. An exception from this seems to be the poured concrete structure of the buildings. Interviews with gang leaders and managers, as well as observation of several incidents and problems during production work, indicated notable complexity both in the course of the production runs as well as in the emerging concrete structure.

A second area were high complexity could be observed, was in the integration of subsystems in certain locations in the built object. An example of this in project K was unanticipated effects of enmeshing of several systems inside an internal wall, making the wall - itself a system with a sandwich structure and a hollow core - unstable and losing its shape under high-humidity conditions.

The dominant form of complexity, however, as observed in Project K during the field work, was clearly in the construction project itself, where activities are divided into operational work packages and organized temporally and with respect to intra- and inter-elemental dependencies. This, of course, is the functional essence of standard project management tools. These are able to model how work teams and their activities are to run alongside in the course of the project. The project model represents a framework for coordinating the dynamic production system of the construction project.

What was found in the ethnographic study is that this administrative framework, even though essential for the outcome of the project, is only “scratching the surface” of what is actually going on in the production work. Real-life efforts have to deal with a level of detail that cannot be replicated in the project model. Observations indicated that neither the designs (in project K in the form of conventional paper drawings) nor the progress plans had much to say about the everyday working out of practical solutions that could make production flow and the built object emerge in line with overall plans.

To explain why this is so, one could metaphorically described the everyday problem-solving as going on at a “level of reality” existing "beneath" the progress plans and design drawings created by architects, engineers and project managers. Obviously, it is on this detailed level of tangible reality that energy, skills and creativity are employed to effect the transformation of materials and components into the built object. It is here that discontinuities and contradictions are hit upon and the processes of finding solutions have to start. There are numerous observations recorded in the observation log from the fieldwork that document examples of this. For example, it was observed in one case that parts of iron did not have the right measures for a support wall and re-ordering of correct parts would take too much time and have serious ripple-on effects; in another case that architect’s drawings contained errors due to omitting the inclusion of fire inhibiting materials; in a third case that different drawings were incompatible because designers had failed to communicate and agree on a single design, and in a forth case that people fell sick and did not show up for work. Such seemingly trivial examples are interesting here, because they represent situations in which complexity becomes obvious and complexity management is essential to keep up production flow and avoid having to backtrack and rework.

There were, however, also more subtle efforts to cope with complexity that were observed during field-work and found to be common occurrences. As mentioned in the discussion of methods earlier, an analysis of the handling of discrepancies, contradictions and imperfections was made based on an in-depth interview in which problems made explicit in meeting minutes were discussed. Extract 1 contains excerpts from the interview with management team member X in project K.

*Extract 1: Knowing and negotiating floor elevations*

> The elevation of floor surfaces [in one story in a building] is like a game. A very scary game, it is. (…) It all depends on the progress plan, but you know, stairways and balconies (…). Sometimes the stairs come first, at other times the balconies are poured first. (…) So this is challenging and you really have to proceed cautiously. Where you place windows, where you position doors, where you place kit and caboodle ... because everything can become crazy expensive. (…) Everyone [in the industry] is struggling with this. (…) Sometimes you have to plan a doorstep to make it (…). And sometimes, if you have to put in a prefabricated bathroom cabin (…) then that is put on top of the concrete floor and then you have a doorstep that has to flush with the cabin door. And if you also have sliding doors then the floor has to flush perfectly with that and with the balcony outside, and then you might have to pour a bit less here because this surface is to be tiled, and there, and here because of the hardwood flooring.. Foreman Y has been extremely competent, he has taken this as the point of departure (…) and has said to the lads pouring the balconies that they should use that as a reference at least in front of the door, which is the most important. Then we have made a detail drawing, and shown how to proceed with that. For example, with these flats: [pointing in the drawing]; one, two, three, four and five, we have said here is the door, here is the door, here is the door, here is the door. Then we have proceeded in this way: this is the level of the stairs; this line is the line indicating this level; here it should be 1 cm under this line. Then we have tried to adjust and to calculate the height difference relative to that line, all the way, tried to adjust everything, and said, like, hey, here there is the possibility to gain 5 millimetres. And then we have talked to the float-floor people and said you can make the floor with this level here. And over time, the [float-floor guys] (…) became so good at this that they could see themselves what was needed and what doors we could use, to create a level difference of maybe 5 millimetres on the floors [and succeed in keeping within the tolerance in over the whole story].
>
> Interview with X in the project K management, January 31, 2018. [Author's translation]

This is but one example of several possible in the observation material, and is presented here to show how production work is a complex and creative reality underlying the level of structural drawings and progress plans; and for other reasons than that errors are made. X focus only on the technical systems; it is the mutual adjustments that have to be made between several elements, and the possibility of ripple-effects that have to be controlled. As for built-quality-as-realized-in-production, this is the essential integrative effort that construction workers and their management on-site have to accomplish. This in itself is a complex issue, since so many work teams are involved and need to communicate, negotiate and agree, for a workable solution to be found and economical working procedures established.

In terms of complexity management in the real-life activities underlying structural models and plans, this is far from all, however. The people involved have to deal with a number of other systems than the technical, and at the same time. Most obviously, work has to be done economically - all involved are conscientious about their remuneration and what has to be done, to avoid negative economic effects. Another issue is safety; those involved are aware of the safety guidelines and regulations that they have to comply with. And as a matter of course, they are concerned with maintaining their relations to other workers and teams, in particular maintaining or improving their place in the social system of the work group that they are part of.

Sorting out the technical issues, therefore, is far from only a technical issue. Non-technical considerations normally play a significant role for the ability of workers to realize acceptable built quality on-site. This was observed and documented during the ethnographic fieldwork in Project K, where an overarching concern of the project management was to "keep the lads happy"; by balancing administrative demands and requirements with the need to keep a positive tone in the project organization.

# CONCLUSION

The question was posed at the introduction how can we account for the many deviations and for the insufficient built quality encountered in many building projects, when errors, deviations and contradictions in project based production of the built environment cannot be explained simply by pointing to human inability or unwillingness to carry out what is suggested in pre-made designs and progress plans. The argument has been made here that managing complexity is a significant factor in safeguarding built quality as realized in project based production. There is a significant overlap between enhancing built quality and work-based managing of complexity. Complexity cannot be avoided in large systems, but it can be managed. Part of this complexity management effort is handled in decentralized administrative quality control systems, as when routines are implemented by plumbers to sign off on batches of work and document what has been done with pictures stored in their own project documentation archive. But another significant part of the quality management is carried out by workers in everyday project practice, in informal ways.

Further exploration of existing data and also further empirical research would be needed to expand the analysis presented here; to more systematically document how various systems complexities are managed, what the positive role of administrative quality systems can be in the overall context of practice, and how such systems ought to be designed not to interfere negatively with workers' own complexity management efforts.

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