CONSTRUCTION MANAGEMENT IN A COMPLEXITY PERSPECTIVE

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Abstract: Construction management is based on the Newtonian principle that the construction process can be foreseen and planned, and that the plan can be followed through the whole project execution. Deviations between plan and reality are seen as planning errors, which more diligent and detailed planning might have taken care of. Based upon Koskela' explanation of construction as a production this understanding of construction management has been criticized lately.
The paper endorses this critique but argues that construction must not only be understood as a production, but should also be seen in a complexity perspective. This view brings not only Lean Construction's broader understanding of project management into play, but introduces a completely new management approach as well. These ideas may seem unsuitable in construction, but recent Danish experiences show their value, and a new initiative in the Danish construction industry uses them as its basis.

Keywords: complexity, project management, lean construction, implementation, life long learning

1. INTRODUCTION

The construction industry, and thus its project management is adversely known for its performance: Inconsistent value generation, frequent cost and time overruns, low quality, bad safety records and harsh working conditions … Indeed, anyone who has endeavored into the role of client of a construction project has his own experiences to report. (Latham 1994, Egan 1998)

Over the years much effort has been made to correct this undesirable situation but without any real success. Introduction of production management tools such as value engineering, value management, quality assurance, safety management along with the well reputed project management tool: CPM and a number of ingenious cost management systems has – and in the best cases only – caused marginal improvements. (Dræby 2000, By- og Boligministeriet og Erhvervsministeriet 2000)

More and more it becomes clear that something must be wrong. When the rational, engineering approach again and again produces no better outcomes, a completely new thinking may be called for.

This paper argues that it is the understanding of the construction process that is incomplete. Construction projects are by and large managed by engineers and at best advised by economists, but these distinguished disciplines are both based on an understanding of our world and its living systems, which fundamentally is more than 300 years old. Within the last decades a new understanding of life, living systems, and by that the understanding of social systems such as organizations, societies and, indeed even Mother Nature and the universe in general has gained more and more foothold in science. The complex systems theory is indeed here to stay. Ordered, Newtonian systems exist only in theory, the real world is a mess.

The paper sets out by outlining the nature of complex systems. It proceeds by reviewing some recent critique of the prevailing understanding of project management and it introduces a new approach in the light of work undertaken within The International Group for Lean Construction. It then introduces some new management principles based upon the complex

systems understanding, and it concludes by outlining a recent Danish construction industry initiative based on these ideas.

2. COMPLEX SYSTEMS

Complex systems are natural, they have always been here. Our problem is that the Renaissance scientists developed an understanding of the world that was based on their rational calculus. The general skills in calculating had just moved from addition and subtraction to the more difficult arts of multiplication and division, and over the next centuries such advanced methods as logarithms, differential algebra and probability theory were developed.

The strength of the understanding of nature by observations combined with these new methods was proved by great explorations undertaken by naval captains, by the explanation of the universe by Nikolaus Kopernikus and Johannes Kepler and not least by Isaac Newton's theory of the nature of mechanics. Followed by Maxwell's explanation of the laws of electricity, the world in general and science in particular came to believe that nature was predictable. The quest was only to state the situation and to define the formulas guiding the system.

The present state of the system of nature is evidently a consequence of what it was in the preceding moment, and we conceive of an intelligence which at a given instant comprehends all the relations of the entities of this universe, it could state the respective positions, motions and general effects of all these entities at any time in the past or future, stated Pièrre Simon de Laplace (1749-1829) in his Philosophical Essay on Probabilities,

Doubt began to turn up around 1900 with the emergence of the quantum mechanics, which challenged Albert Einstein to the famous statement: *You believe in a God who plays dice, and I in complete law and order,* expressed in a letter to Max Born on the interpretation of quantum mechanics because of the need for dealing with the systems in a purely statistical way. A shock for the established scientific society who then believed that physics now knew almost everything about the world with a few, minor details missing only. The work of Niels Bohr taught them at the same time that the observer and the observed object are not independent – they interact, and the observed system can thus not be considered as ordered in its own right. The act of observing it disturbs the order the system might have possessed before the observation.

Later came the world of complex systems, which can be said to lie between the ordered Cartesian world and the statistical world of quantum mechanics. Today it is more and more recognized that most systems in our surroundings are not linear and ordered but non-linear, complex and dynamic. (Lorenz 1993, Kauffman 1993, 1995; Waldrop 1992) The science of complexity studies these systems and does it in ways that are organic and holistic.

2.1 Complex Systems' Nature

Complex systems offer a series of characteristics, which are not found in ordered systems. Bertelsen (2003a and b) considers this understanding and analyzes construction in three perspectives in the light of eighteen such characteristics taken from an overview compiled by Lucas (2000).

From a project management point of view certain of these characteristics are of particular importance. Among these are *emergence* – the system as a whole shows characteristics that may not be deduced form studies of its elements, *self organization* and *self modification* – the

system is able to create order and change itself, upward and downward causation – the system is affected by its element jus as the elements are affected by the system's over all state as well as unpredictability – the future state of the system can not be predicted in any detail. Bertelsen and Koskela (2003) consider this last aspect in construction.

As complex systems are in their nature unpredictable but capable of self organization and learning, management of such systems can not be based on detailed instructions or plans, but must comprise a statement of the objective, improvement of reliability and distributed control. (Kevin Kelly 1994)

Such management principles can by found in practice at f.i. the US Marines (Fredmann 2000), just as quite a few organizations adopt what a Danish management consultant has coined ant hill management.

3. CONSTRUCTION PROJECT MANAGEMENT

Central in Lean Construction's perception of construction management is Koskela's Transformation-Flow-Value theory (Koskela 2000), which is very much inspired by the work of Shigeo Shingo (1998).

In this theory it is recognized that the prevailing understanding of construction as transformation – a series of operations where materials change form and increase in value – is not adequate. Construction must also be understood as a flow of work and the operations therefore be seen as a whole process, generating the desired project value as specified by the client.

The traditional, narrow understanding of the construction process has led to the idea that construction can be managed by means of contracts governing the transformations only. As pointed our by Koskela and Howell (2002) in their critique of project management the broader understanding leads to more comprehensive project management principles.

Bertelsen and Koskela (2002) introduce a project management approach based on all three aspects in a suitable balance and report the implementation of this approach in the Danish construction industry.

3.1 The Transformation-Flow-Value Theory

3.1.1 Managing Transformation

Managing transformation is the kind of project management most project managers are familiar with. It takes place by managing contracts, establishing quality and safety requirements and procedures, but it frequently leads to what seems to be an increase in productivity but in truth is sub-optimization only.

It is necessary to manage the transformations in construction if for no other reason than because of the huge contract values involved, but this simplistic kind of project management is not adequate in the complex and dynamic system the project usually represents.

3.1.2 Managing Flow

Managing flow in the construction industry introduces several new management activities. One should be to establish a closer cooperation along the supply chain – Supply Chain Management has this been coined in the manufacturing industry. This kind of cooperation should not only comprise cooperation between main contractor and trade contractors, but

should comprise the manufacturers and suppliers of construction materials as well. Another activity should be setting up the logistics for materials and information. Bertelsen and Nielsen (1997) report the effects of such procedures in practise and Vrijhoef and Koskela (1999) investigate the aspects from a management point of view.

The method of Last Planner (Ballard 2000) can be seen as an important tool in managing this cooperation and the logistics during the construction phase.

3.1.3 Managing Value Generation

The concept of value is probably the most difficult to approach in the new way of managing construction projects. Stuart Green (1996) proposes an understanding of the value generation during the early design phases as a learning process between the client and the design professionals. Both parties learn and through this a joint understanding of client's value parameters and their realization in the design is reached. Bertelsen et al (2002) propose a new process for value generation, where a great part of the conceptual design is performed through a series of workshops and where a greater number of the client's stakeholders – often as many as thirty to forty – are involved in the cooperation with the designers in day long sessions. Christoffersen (2003) reports how this approach in practice has led to a shorter and more efficient design process with a substantial higher customer satisfaction and fewer project revisions in the later phases.

The reason for these remarkable results is quite obvious when interpretated through the complexity thinking. Complex systems may give raise to wicked problems and wicked problems should usually be solved by consensus between as many stakeholders as possible. The workshop is the setting for this kind of problem solving and project revisions are reduced by the stakeholders taking ownership to the design solutions.

In recent years partnering as a value generating cooperation has gained more and more foothold in Danish construction projects. Most arguments for this kind of cooperation have been that the number of claims are reduced, but the experiences with the workshop approach may be a new argument for the use of partnering in the conceptual design phase: it is a more efficient way of generating project value.

4. CONSTRUCTION AS A COMPLEX SYSTEM

Generally, project management understands the project as an ordered and simple – and thus predictable – phenomenon which can be divided into contracts, phases, activities, work packages, assignments etc to be executed more or less independently. The project is also seen as a mainly sequential, assembly-like, linear process, which can be planned in any degree of detail through an adequate effort and executed in accordance with the plans. As a consequence, project management acts top down, mainly by management-as-planning as proven by Koskela and Howell (2000).

This paper proposes that the perception of the project's nature as ordered and linear is a fundamental mistake, as the dynamics of the surrounding world is not taken into account. Project management must perceive the project as a complex, dynamic phenomenon in a complex and non-linear setting.

Most systems in the world are complex. And so is construction. This can be seen by the wicked nature of the design process, which is caused by the fact that there is no optimal solution to the problems faced, and where preconditions are defined in parallel with the solutions. The same kind of wickedness is often found in the construction phase. Different

stakeholders have different targets and objectives, but have to collaborate in order to complete the project successfully. Compromise is the way ahead in great many cases.

The project may look like a sequential assembly-like process, and so it is in a distant perspective. But in detail, the process is highly parallel. Many project activities are not inter-dependant and may be executed in any sequence or even simultaneously without any effect on the over all result.

Starting from the bottom, it is up to the individual craftsman to choose his way of doing the job at hand. No formal process description is normally provided, and the industry practice of not interfering across contractual boundaries with the way work has to be carried out, enhances this informality in the low level process design.

But also at higher levels is the process not sequential. The trade contractor may have his own way of executing the job. The weather may change the sequence, and unforeseen events may enforce further changes in the sequence, which to a great extent can be made without any impact on the general schedule.

The plans and schedules present an idealized linear picture of what *should* take place, but not of what actually does take place. Planning does not reflect reality, but dreams!

4.1 Towards a Complexity Approach to Project Management

While the transformation-flow-value theory broadens the understanding of project management, the perception of construction as a complex phenomenon opens up for the introduction of completely new management techniques. The ordered approach which gave rise to what can be called management-as-planning and management-as-organizing must be reinterpreted and supplemented with, management-as-teambuilding, management-as-service providing, and even management-as-a-nuisance. These new approaches, which may all be needed in future project management, are outlined briefly in the following. It is to a certain extent speculation, but the author has participated and is participating in a number of projects where the principles to a certain degree have been used.

4.1.1 Management as Planning

Even though Nature handles complex system without planning, the nature of the construction project calls for an analyzing and planning effort.

This is very much the effort usually undertaken at the outset of the job in question, but with a much more limited scope. The prime objective of the planning is the project analysis, where the work to be undertaken is broken down into work packages and a feasible process along with an overall 'budget' for the available time for the project execution is established. No matter how much this effort looks like the traditional planning approach, this is not the plan for the actual project execution.

As the system is near chaotic, management must be based upon the fact that the execution will be unpredictable in detail more than a few steps into the future. But certain things can be organized such as the ordering of materials and long lead items, just as the contractual arrangements can be set up. By this it is envisaged what *should* take place, and certain steps are taken to make sure it *can* take place.

But planning is not only about putting the activities in order as CPM indicates. It is analyzing the process feasibility and establishing the criteria for success as well, just as it is assessing the complexity and identifying the pitfalls. However, the general guideline should be: don't believe you can plan more carefully by going into deeper detail. You'll only find chaos if you look too deep from your present level.

4.1.2 Management as Organizing

When it comes to the operation of the project, the new kind of management should also look upon its role as management-as-organizing. The important issue here is to organize the execution as a self managing system to the greatest extent possible. In doing this, choosing the right players for the team – and not the cheapest – may be of paramount importance, often just as important as establishing a suitable project management organization.

The superior objective of the organization should be to increase the reliability of the individual agents making it possible to distribute responsibility as much as possible. Any problem should be solved and any coordination be made at the lowest level possible with respect for the over all project analyses. This calls for as few and simple rules as possible. Last Planner (Ballard 2000) is thus a highly suitable tool for the delegation of responsibility for making sure that things *can* be done and – more important – that they *will* be done.

Indeed, in Denmark we more and more see planning on all levels as commitments. The phase plan is a commitment between the trades on how we *should* execute the project. The Look Ahead plan is a commitment to make sure that we *can* execute the assignments, and the weekly work plan is a commitment between the crews on what they *will* do in the next week.

As claims and costs issues usually seem to hamper any form of positive cooperation in construction, a fruitful strategy may be to keep money-issues away from the construction site as much as possible. In Denmark this has been done by introducing a special process management parallel to the ordinary construction management, which mainly takes hand of the contractual – and thus the financial – issues. The process management is thereby free to focus on the on-site productivity mainly (Bertelsen and Koskela 2002).

An important part of the process manager's function is to ask and listen, and not least show confidence in the professionalism of the man 'on the floor'. A few Danish experiments using *multi skilled and self managing gangs* have shown remarkable improvements in productivity. The reason is obvious when looking from a complexity point of view: The multi skilled gang reduces the complexity in the both the production and the human systems and at the same time moves problem solving downwards in the organization.

4.1.3 Management as Team Building

Projects and project participants are all different and the big challenge facing the project manager – which most business manager is lucky to be almost without – is the need for establishing a construction site team spirit almost immediately. The culture of cooperation must be established from the very beginning and kept up all the time. Also service and support must be in place in order to gain confidence, and of course: the project's targets must be clear and communicated, particularly if the project is one where frequent changes may be expected.

As the project is executed by a temporary production system and the construction site is likewise staffed by a temporary and very transient human system, team building becomes of great importance. Usually the welfare of the crew members is considered the sole responsibility of their own company. But understanding and managing construction as a complex, dynamic system makes it necessary for the project management to take over a great deal of this responsibility.

The team is new. It is brought together for the project and its members are not chosen as team players but by the lowest cost. They are not the project's employees but leased for the job from their home firm, which probably has other criteria for success than the project in question, and their involvement in the project has thus the nature of hit and run. As the design is new and the site is unbroken, nothing at all is as is it was in the former project. And a new project may often have its very own criteria for success. Thomassen (1999) analyses this

aspect of cooperation and treats it as a Prisoners' Dilemma, which indeed may be a precise way of studying the lack of cooperation in construction.

The success of the project becomes very dependent on the wellbeing of the workers, just as the success of any firm is dependent on its employees feeling at home on the job. The process management should thus initiate team-building activities, and at the same time strongly support a distributed management. This may take place as special sessions, but more important, the team thinking should be an integral part of any kind of flow management. Plans should not be seen and understood as orders but as conversations. Hal Macomber (2001) proposes this approach in a distributed kind of process planning, where planning is understood as making and keeping commitments, and Macomber and Howell (2003) take this approach a step further in their reinterpretation of the Lean Construction basis as linguistic action with an outset in Fernando Flores' (1982) ideas. Elsborg et al (2004) report an approach to this kind of cooperation on several construction projects, where the guiding principles were learning and entrepreneurship.

4.1.4 Management as Service Providing

Lean Construction distinguishes between two kinds of activities in accordance with Shingo (1988): Value generating and non-value generating. Obviously, value-generating activities should be executed as effectively as possible, whereas non-value generating activities should be minimized.

Looking at the construction project from this perspective gives rise to a somewhat surprising observation: *Almost any management activity is non-value generating.* Management must thus be understood as a provider of service for the value generating activities, fi by providing the right materials, equipment and information.

It seems probable that this understanding of the role of the project management will be the most difficult to accept for the traditional project manager, being used to be the guy in command and the one issuing orders and instructions in great detail.

However, if one looks at the construction site's operation in detail, it can often be recognized that the trade contractors' gangs are left on their own. Tavistock (1966) pointed to that and Nielsen and Nielsen's (2001) studies of the use of time on a Danish construction site showed that insufficient logistics was a great source for wasted man-hours. The crews lacked an engaged and effective support from their home office. The reason is obvious. The trade contractors have other priorities than optimizing the workflow at any particular project. To them the key to higher profit is to optimize the use of their total resources, i.e. their crews and their equipment.

As the process management takes over more and more of the responsibility for ensuring sound activities by establishing an efficient support and back up, they are taking over the workers' professional welfare as well and by that making them feel welcome on the site. Such efforts will inevitably move the workers' loyalty and focus away from the home office and to the project's success.

4.1.5 Management as a Nuisance

All in all the new kind of management can to a great extent be characterized as management-as-a-nuisance. Management should interfere with the project execution as little as possible without letting the whole process turn into chaos. This recognition sounds very much like Per Bak's (1996) observations of natural systems, which seems to behave in an optimal way when left in a situation of self-organized criticality.

Now, this may sound quite easy. Just let the system take care of itself as much as possible - but it is not so. Self-organized criticality means that a cascade of unforeseen events – smaller

or larger 'catastrophes' – will take place as a part of the system keeping itself in the optimal position. Most of these events will be small, but they will occur, and a few will be larger.

How does a responsible management report to its superior level, that these events are just what have been expected and that they should not be avoided, as they take the strain out of the system and hopefully add to its learning?

Indeed a huge challenge!

5. BYG.SOL – A RECENT DANISH INITITAIVE

The above new understanding of project management as management of complexity, where delegation of responsibility, cooperation and learning should be central principles is being tested in practice in the recent Danish initiative: Lifelong Learning in Construction – Byg.SoL. (2004) (The abbreviation Byg.SoL stems from the initiative's name in Danish: Samarbejde og Læring i Byggeriet). This initiative has been taken by parties within the industry and funded partly by the European Social Foundation and partly by the industry itself. Its aim is to develop and implement a new construction process yielding higher value and lower costs.

Throughout the last fifteen years the Danish government has taken a series of initiatives in order to increase the construction industry productivity and to this end a great number of experiments and studies have been undertaken, and several white papers have been prepared. (Bertelsen and Nielsen 1999) This has established the challenge for the sector and by this initiative some of the leading participants within the sector have taken the challenge upon themselves.

5.1 Objective

The initiative's main objective is to implement a new industry practice in the design and construction processes. This objective indicates that it is no longer time for experiments but for direct action, which therefore requires strategic commitments by the management of the participating industries.

The better practice aimed for also calls for a change in attitude and behavior throughout the industry – from the management and down to the last worker employed on the construction site, and from the clients through the professionals and to the contractors and suppliers of materials and equipment.

This development calls for an ongoing learning process comprising each and everybody working within the construction sector, not least the many skilled and unskilled workers employed on the construction sites but also professionals, contractors, suppliers and clients.

As elements of this objective the initiative will:

- Establish a better cooperation in specifying project value for the client in the early design phases and introduce mutual learning as well as value management principles to ensure that the specified values will be delivered
- Establish a better cooperation between consultants and contractors during the detailed design and construction phases in order to better design constructability through a learning process and to improve the flow of work, materials and information and thus reduce waste.
- Establish a learning based site management training – from foremen over superintendents to site engineers – by putting focus on cooperation, teambuilding and training.

- Establish mutual learning and a better cooperation on the operations level between the gangs and the individual workers across trade boundaries and involve the workers in the day to day planning of the operations
- Establish increased quality and workers' safety by further utilizing all the competencies by all personnel working on the construction site and stimulating them to further learning.

6. CONCLUSIONS

Lean Construction has over the last decade provided construction with a very much needed new understanding of the construction process and its organization. This is important from a scientific point of view, but much more so as the industry challenged in its performance has now taken this understanding as the basis for a scientifically based rethinking of the construction process.

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