

AVOIDING AND MANAGING CHAOS IN PROJECTS

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ABSTRACT

Construction projects are often very complex and dynamic by their nature, and it is a well-known fact that such systems exist on the edge of chaos. The paper's objective is to study construction projects poised on the edge of chaos and to explore the forces that may turn projects chaotic in the sense that the project crosses this dangerous edge. The prime aim is to understand how the phase transition may take place and to propose an approach for understanding this risk and keeping it under control in project management.

The paper explores this understanding of the construction project further by proposing a way of analyzing its complexity and dynamics along the four characteristics: the project's complexity, the project's internal and external setting and the project organization. The aim is not only to reach a deeper understanding of projects' nature, but also to outline a tool for analyzing and comparing projects' risk of turning chaotic. However, before addressing this main theme, the phenomenon of chaos in a project is introduced through a literature review and illustrated with empirical project cases.

Complexity was identified as an IGLC championship at the IGLC-9 conference in Singapore in 2001 and was included in the theory championship at the IGLC-10 in Gramado, Brazil in 2002. The paper is contribution under this championship.

KEYWORDS

Project management, construction, complexity, order, chaos theory

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INTRODUCTION

Construction projects come in many varieties depending on the nature of the constructed artifact and the associated construction process. However, a project cannot be understood in its own right only, its setting is of great importance to its execution. The setting consists of three characteristics of the project environment: The internal setting describing the stress condition in the construction system such as pressure for short construction time and budget restrictions; the external setting describing the availability of the project preconditions such as directives, prerequisites and resources; and the project organization. These project characteristics interact and together they form what can be called the project theatre.

It has been shown (Bertelsen 2002, 2003a) that construction systems are highly complex and dynamic. Nature as well as our society is very rich in systems of this kind. Indeed almost any system can be claimed being complex and dynamic. But until the last decades the nature and behavior of such systems have not been generally studied and understood in greater detail, not least their capability of changing from an ordered to a chaotic state through a phase transition.

Bertelsen (2002) claims that the understanding of construction from this perspective opens up for a new explanation of the success of the Last Planner method and gives strong arguments for the new kind of project organization and project management, advocated by the lean construction society (Koskela and Howell 2002a and 2002b, Bertelsen and Koskela 2002, Bertelsen 2003b).

The paper sets out by reviewing some research on the issue of complexity in construction. It then proceeds by exploring half a dozen projects that have turned chaotic. In this we are distinguishing between chaos in-the-small and chaos-in-the-large. Chaos-in-the-small refers to a most common situation in construction, where the short-term developments (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. It is argued that chaos-in-the-small may very fast turn into chaos-in-the-large if not observed, understood and kept under control.

Consequently the next section proposes a method of analyzing the project's complexity and dynamics in order to get a feeling of the forces positioning the system and these forces are put together in a systems model describing the project setting in relation to the edge of chaos. Finally some thoughts on the use of the model in practice are presented along with proposals for further work.

CHAOS IN A PROJECT

WHAT IS CHAOS IN A PROJECT?

Why should we avoid chaos in our projects? To answer this question, it is necessary to define the concept of chaos. Chaos may be defined as a state of the (project) system where the future development of the system is not predictable, or only poorly predictable. Depending on the angle of consideration, we may distinguish between chaos-in-the-small and chaos-in-the-large.

Chaos-in-the-small³ refers to a most common situation in construction, where the short-term developments (acts by different parties) cannot be accurately predicted, due to the joint impact of interdependence and variability (Tavistock 1966). However, regarding the progress of the project as a whole, we can pretty well predict its development: the building will be finished at due time or almost. Thus, the amount of earned value is more or less constantly increasing.

In contrary, chaos-in-the-large means a situation where the progress of the whole project cannot be predicted. Often the question is about a situation where the progress is not proportional with the effort, as illustrated by Brooks' Law (1995) about the Mythical Man-month. In such a situation the amount of earned value, at least in retrospect, is not increasing – it may seem to increase, but later developments show that the work accomplished was not usable, and had to be substituted by rework. Uncertainty about the probable finishing date and the total cost is a hallmark characteristic of chaos-in-the-large. However, the impacts of such chaos may also be channeled into reduced value and functionality, instead of cost and duration.

Chaos-in-the-small is a nuisance that adds to costs and decreases the quality of the output. Construction professionals have learned to live with it, and recently methods have been devised for stemming this form of chaos (Ballard & Howell 1998).

However, Reppenning et al (2001) show that chaos-in-the-small – which they name 'firefighting' – can turn into chaos-in-the-large, possibly spreading out over the project's boundary to neighboring projects. And as could be expected, chaos-in-the-large is not only a big nuisance, but may be fatal for the participating organizations. It adds vastly to cost, it may jeopardize the whole rationale of the project.

In the following, we address primarily chaos-in-the-large. However, chaos-in-the-small may escalate to chaos-in-the-large, and so the focus cannot be restricted to the latter only.

WHY DOES CHAOS EMERGE?

In prior literature there are different explanations to the question, why chaos emerges in projects. Cooper et al. (2002) pinpoint three interrelated factors related to the dynamics of a project: the rework cycle, feedback effects on productivity and quality impacts, and knock-on effects from upstream phases to downstream phases.

Cooper notes that the conventional project management does not acknowledge rework. Customarily, more or less rework emerges in any project. At least part of rework lies undiscovered for a considerable time, and after its discovery, it is rushed to completion, competing with other work assigned to the specialists in question.

Feedback effects on productivity and quality refer especially to the situation where there is managerial corrective action after deviation from the plan. Bringing more resources, using overtime or exerting schedule pressure will usually reduce productivity and quality. Reduced quality will, in turn, lead to more rework.

When a project consists of several phases, the availability and quality of upstream work can impact the productivity and quality of downstream work. Thus, the rework cycles and

³ It is chaos-in-the-small, or "normal" variability of production, that up till now has been primarily addressed by the proponents of lean construction. We suggest extending the focus to cover chaos-in-the-large, too.

feedback effects in one phase extend their influence to the next phases. Repenning et al (2001) demonstrate the existence of a tipping point above which the effects accelerate whereas they die out below this point. Chaos thus occurs as a phase change when the project passes this point.

Fyall (2002) endeavours to quantify the amount of rework (in the case of design projects) leading to turbulence in information flow (which can be associated to chaos). He discovers an equation, including the probability of errors in tasks, the degree of task interdependence and level of centralization, the value of which predicts when the system will slip into a chaotic condition.

Williams et al. (1995) analyze the effects of parallelism in projects. They argue that if in a design project interrelated parts are designed in parallel activities, this causes the activities to last longer, due to the added effort of capturing input data from other activities. This leads to more parallelism, but also to other loops. More work has to be done on unfrozen items, there is more competition on limited, trained resources, and inevitably, increased delay results. Thus parallelism, motivated by time pressure, is liable to cause delay.

A team of INSEAD scholars (Pich et al. 2001, De Meyer et al. 2002) have recently analyzed the requirements set by projects differing in regard to their uncertainty. They distinguish four types of uncertainty: variation, foreseen uncertainty, unforeseen uncertainty and chaos. Let us concentrate on chaos. It is described as a situation where a project cannot be based on reasonably stable assumptions and goals. The basic structure of the project plan may be uncertain, and the project may end up with results completely different from the original intent. Thus, in this case chaos refers to situational factors of the project.

De Meyer, Pich and Loch suggest using two strategies jointly for projects subject to chaos: learning and selectionist strategy. Learning comprises scanning for unforeseen uncertainty and related original problem solving to modify policy or goal. Selectionist strategy comprises multiple trial and error, and selection of the best candidate.

One contributory cause for chaos, discussed by Dörner (1996), is the cognitive limitation of human decision-making. He characterizes complex situations as follows. First, the question is about complexity, the existence of many interrelated variables. Second, we have to deal with dynamic systems. It is not enough to manage the system a single moment, but over time. Third, the system is to some extent intransparent; we cannot see all we want to see. Fourth, ignorance and mistaken hypotheses prevail. We usually do not know all relationships between the variables.

Dörner (1996) goes on to explain the generic causes of mistakes people make when dealing with complex systems:

- slowness of thinking
- small amount of information that can be processed at any one time
- limited inflow capacity of the memory
- tendency to protect the sense of competence
- tendency to focus on the immediately pressing problems.

However, Dörner claims that the impact of such cognitive limitations may be reduced through reflection on our own thinking and through simulation of complex and uncertain systems.

EMPIRICAL CASES ON CHAOS IN A PROJECT

For illustrating the significance and prevalence of chaos in construction projects, a number of cases are presented in the following. The causes of chaos are subjected to an initial analysis.

Sydney Opera House⁴

Chaos: The project budget escalated from \$7M (Australian) to \$107M and the construction time from 4 years to more than 14.

Interpretation: The decision on this very complex building project was based on sketch drawings. The form of the roofs was challenging from a structural as well as from a construction method point of view. The organization of the project was ambiguously structured and the decision power was thus weak.

Denver International Airport⁵

According to the plan, the project was to span 1989 - 1993 and to cost \$1.7 billion.

Chaos: The opening of the Denver International Airport had to be delayed four times due to problems in the baggage handling system. The total delay was 16 months. The total costs were \$4.5billion.

Interpretation: Several factors contributed to baggage handling system problems, ranging from deficient scheduling, novel and untested technology, complexity of the system and changing requirements.

Cumberland Infirmary⁶

The question is about a new hospital building in Carlisle, UK, built according to the PFI (Private Financing Initiative) scheme in 2000. The hospital has 442 beds. The building cost was £87M.

Chaos: The new hospital has attracted notorious publicity through sewage spills from sinks in the operating theatre, collapsing ceilings, walls so thin that shelves cannot be installed on them, flooding cardiology and maternity wards, excessive summer temperature due to lack of air conditioning, frequent electricity outages, space saving leading to removing of doors (that couldn't be opened without banging them on beds) and costly redesign of resuscitation trolleys for getting them into the wards, etc.

Interpretation: The project seems to have led to undiscovered rework needs, massively dysfunctional solutions hindering the normal operation of the hospital, and image losses. The

⁴ Source: (Kharbanda & Pinto 1996).

⁵ Source: (Drexler, Hans & Käck 2002)

⁶ Source: (Browne 2001)

immediate reason seems to be a stress situation caused by the management's endeavour to keep the cost down, but also lack of experience in hospital operations in the client's organization may have contributed.

Industrial plant in the U.S.⁷

The intention was realize this \$100M. project in a fast-track mode, with a total duration of 27 months, and a design period of 14 months overlapping the construction phase of 21 months.

Chaos: The construction phase started 5 months behind the schedule, and lasted 26,5 months. The plant went into operation almost 10,75 months behind the schedule.

Interpretation: According to the analysis of Fazio et al. (1988), 66 % of the total delay can be attributed to fast-tracking – and thus the project dynamics, probably with some added stress – either directly or indirectly.

Nuclear power plants in the U.S.⁸

Chaos: Reported progress, cost projections and remaining projected project durations are consistently and repeatedly more optimistic than actual achieved results.

Interpretation: There is a minor and major rework cycle, the former leads to rework in the previous phase, whereas the latter leads to rework in several previous phases. This interactive and cumulating rework, when undiscovered, leads to the consistent, significant variation between actual progress and projected progress. The stringent regulatory requirements of the nuclear industry contribute to the high level of rework. This reflects an uncertainty in the preconditions for the work package and thus an increased project dynamic.

Office building in Denmark⁹

Chaos: More than three times the working hours estimated were needed.

Interpretation: Due to unclear work specifications, the client's incentive to follow the schedule and a poor decision logistics, a number of tasks could not be carried out in the right sequence. Parts of tasks were left to be completed later. However, such a completion turned out to be especially ineffective due to lack of motivation, the question being about small tasks all around the building, and continual problems with logistics. In this case, the dynamics of the project grew uncontrollably due to logistics failures.

Dry walls for office rooms in a former industrial building, Denmark¹⁰

The project was urgently needed and was undertaken as a design and build contract.

⁷ Source: (Fazio et al. 1988)

⁸ Observations from several projects, source: (Friedrich, Daly & Dick 1987)

⁹ By the first author.

¹⁰ By the first author.

Chaos: There was not adequate time for the client's approvals, which made the contractor proceed without approvals in order to fulfill the contractual obligations, leading to an unsatisfactory and defective result.

Interpretation: A high stress combined with the organization's inability to make decisions.

PROJECT COMPLEXITY ANALYSES

When a project *has* gone wrong it is often quite simple to tell the reasons why, even though hidden flaws may need to be uncovered (Williams et al. 1995, 2003).

However, what we seek is a tool assisting project management in assessing the risks at the outset of the project and before it turns chaotic, and in pinpointing the sources of such risks. In real life projects this can not be done by the methods used for the post mortem analyses such as reported by Williams et al. (1995, 2003), because *unlikely events are likely to happen because there are so many unlikely events that could happen*, as the Danish physicist Per Bak (1996) stated.

We seek here a method in respect of the principles of complex systems studies, where one should look at the system as a whole without a reductionistic approach and where the relation between the elements are of the same importance as the elements themselves. Also we accept the non-linearity of the system making it hard to establish simple formulas¹¹ for calculating the risk factor.

Thus, what we propose is a method conveying the seat-of-the-pants feeling the experienced project manager often has to the less experienced project manager and at the same time providing a tool for the experienced manager to clarify, analyze and explain his gut feelings.

BASIC COMPLEXITY

The starting point in our understanding is the simple and ordinary project undertaken in an easy pace by a well-established organization with no fuss of any serious kind. This project is ordered as much as can be expected in a one-of-a-kind undertaking and it can be planned and executed almost in accordance with the plan. Even though any project has some uncertainty, this basic project belongs to the extreme end of the continuum– it has no risk whatsoever of turning into a chaotic state.

Even though it may be boring to undertake, this is the project to which we may compare our project in question.

PRODUCT AND PROCESS COMPLEXITY

These are issues that generally can be identified at the outset. They comprise questions such as:

- How complex is the building as an object?
- What is the complexity of the required construction processes and its technology?

¹¹ One example of such a proposed simple formula is in (Kim and Wilemon 2003).

- Do the site conditions, the site access or the construction season add further to the complexity?

These questions should clarify how far from the good old stodgy project we are. Such analyses are often performed in practice, for instance in the form of buildability analyses.

THE EXTERNAL SETTING - THE PROJECT'S DYNAMICS

A lot of unforeseen things may happen during the project execution. These things refer in general to one of the seven preconditions for a sound activity as identified by Koskela (2000). However, these seven preconditions are here divided into three kinds of constraints: directives, prerequisites, and resources in accordance with Ballard (1999).

DIRECTIVES

Directives represent declarations, rules and guidance for the project. Directives answer the questions what, where, how, and how well? Customer conditions of satisfaction, company policy, laws, regulations, procedure, standards, and specifications are all directives. Directives stem from issues in general being outside the project execution team's control. Their uncertainties may comprise:

- Changes
- New client requirements
- Authorities' requirements
- The construction season

The uncertainties may also stem from changes in the project's macro environment; for example, changing economic outlook, changed competitive situation for the project sponsor, etc. They do not hit any task directly, but indirectly.

PREREQUISITES

Prerequisites – or input – as a class represent action that must be taken prior to the performance of another activity. A better way to understand this is to define the conditions upon which work can proceed or is released. Work performed by others or by oneself is a prerequisite, providing material (whether in the course of performing the project or as a supply to the project), decisions and authorizations or permission to act.

Prerequisites stem from issues inside the project's universe and are usually under control of the execution team. Their uncertainty may comprise:

- New or unknown construction systems and methods
- Site uncertainty – soil, pollution, hazardous waste, ground water
- Artistic details which must be decided along with construction work
- Unreliable supply of materials or long lead items
- Supply of drawings and specs – if the design is part of the contract

RESOURCES

Resources carry a load or have capacity. There are three resource types: machines, space, and labor. Some people expect to find material in this class. Material however doesn't have capacity. It belongs in the class of prerequisites (Ballard 1999).

Resources stem from the supply system surrounding the construction process and their uncertainty stems from whether the production apparatus can be established.

- Are the crews available when needed?
- Can the equipment be provided?
- Do we have sufficient space?

TOTAL DYNAMICS

The total of the above three kinds of uncertainty gives the project's total dynamics caused by the constraints' uncertainties, which may cause disturbance to the project's schedule, which again – in order to utilize the resources in the best way – may change the sequence of non-critical activities (or even the categorization of activities into critical or non-critical).

The formula for adding project constraints is not just a simple addition, in contrary to the view of Kim and Wilemon (2003). For one reason because the elements strengthen each other as shown by Williams et al (2003). An ordered approach may thus propose a function like:

$$\text{Dynamics} = D + a*P + b*R + c*D*P + d*P*R + e*R*D + f*D*P*R$$

where D = directives, P = prerequisites, R = resources and a ... f are constants.

But in our understanding it is not possible to establish a usable function at all because of the complex and dynamic nature of the system. As we see it, the only approach is thus to make a qualified estimate in the format: small, medium, large, extra large.

DISCUSSION

The combination of constraints depends on the point of view we adopt. Some constraints such as drawings and specifications may change from being prerequisites to directives or resources depending on whether the client is a part of the system being analyzed, or whether we are looking at a design-build contract or the execution part of a design-bid-build only. As previous activities are one of the prerequisites, these may be influenced by uncertainties in upstream activities' directives or resources.

The grouping is thus project dependent but as all the uncertainties should be combined, this will probably not be of great importance for the final outcome. Indeed, the discussion itself of the nature of the uncertainties may give rise to a deeper understanding of the project's nature.

THE INTERNAL PROJECT SETTING – THE PROJECT STRESS

Against these external uncertainties causing the project's dynamics stand some process requirements laid down by the client or given by the nature of the project, putting more or

less stress upon the project execution. Such project requirements can be demands for adhering to the schedule, the budget or requirements for a certain – higher – degree of perfection, i.e. a zero punch list.

Different projects have different process requirements and thus a different stress.

TIME

More and more projects are executed with a demand for short construction time – and particularly a timely hand over. This is often found in projects for factory plants, shopping malls, and not least facilities for the IT industry. But more and more office buildings and even housing schemes have such requirements as well. The demand nearly always leads to simultaneous engineering and construction, adding to the project's stress along with the constraints' uncertainty.

BUDGET

Some projects are also executed with very tight budgets where strict adherence is demanded, whereas other projects may have more flexible budget constraints.

Clients nearly always claim that respect for the budget is of great importance, however this is not the whole truth when putting this requirement up against the similar often stated requirement for timeliness.

GENERAL PERFORMANCE REQUIREMENTS

In addition to the time and budget requirements, there also are often some general performance requirements adding even more stress to the project. One such requirement could be the degree of perfection as expressed by the acceptable number of errors and omissions at the time of hand over – the length of the punch list – as seen in nuclear power plant projects. Some contractors claim that they are capable of delivering projects with a zero-punch list, but when studied closer they more obtain this goal by finding and correcting errors through a giant effort before the hand over. This may seem satisfactory for the client and the contractor's marketing department, but it increases the stress on the project by adding an often uncoordinated and accelerating correction process as the completion date comes closer.

Other general requirements may be such issues as special environmental considerations when working in arctic areas or special workers' safety considerations in nuclear power plant rehabilitation.

TOTAL STRESS

Now we should be able to estimate the total stress. The problem is similar to the one stated previously because the complex situation of the stress cannot be expressed in linear formulas either.

THE PROJECT ORGANISATION – THE DECISION POWER

The last factor in evaluating the risk of chaos is the decision power in the project organization, which acts as the controlling force in the project's otherwise inevitable route over the edge.

High dynamics and stress tend to drive the system towards the edge of chaos. However, the project system's decision power pushes against that movement. Again three elements in the strength can be identified: the client's organization, the construction team, and the parties' cooperation.

Dörner (1996) claims that lack of transparency, ignorance and mistaken hypotheses are the major issues on the decision power side. In our interpretation especially lack of transparency might be classified as a system feature but also mistaken hypotheses may be diagnosed as a long feed back loop between the problem and the problem solvers.

THE CLIENT' ORGANIZATION

The client's organization is of great importance to the project staying in the ordered regime. Often the internal cooperation is not suited for the project's turbulence, where conflicting interests hidden in the established procedures of the daily operations come to the light. This internal mode of problem solution can thus be of great importance to the project's success. To this should be added the client's decision power when it comes to the project's own problems such as his approval time for design solutions: the decision robustness – does a decision stand; the decision power – how many in his organization should have a say; and his delegation of responsibility – how many layers of approval are needed? The analyses in Williams et al (2003) shows the great contribution of the client's – from his own view – rather innocent lack of decision power to the project's failure.

THE PROJECT TEAM

Also the project team's internal cooperation is of importance to the project execution. Again one should look for conflicting interests between the parties and their mode of problem solution, along with the parties' own decision power.

THE PARTIES' COOPERATION

Finally the cooperation between client and construction team should be considered. This includes the parties' previous experiences as a team, the management involvement in the project, the way of solving conflicts, and the project's claim settlement policies and system.

PUTTING THE FORCES TOGETHER

Having analysed the forces it is time to put them all together.

Two of the forces, dynamics and stress, drive the system towards the edge of chaos whereas the decision power tries to keep it on the ordered side. Thus we have a situation which – inspired by the analysis presented by Jens Rasmussen (1995) for safety in general and proposed by Howell et al. (2002) for safety in the construction project – can be mapped as shown in Figure 1.

The size of the battleground is decided by the basic complexity. The more complex the project is, the lesser room for dynamics or stress against a given decision power there is. At the outset the project will normally be situated somewhere in the area on the ordered side of the edge of chaos.

Dynamics and stress drive the project towards the edge, whereas the decision power tries to keep it on the ordered side. The important issue is keeping the project in a safe distance from the edge, making sure that minor fluctuations will not turn the system into a chaotic state, which as mentioned, may come almost instantly as a phase transition.

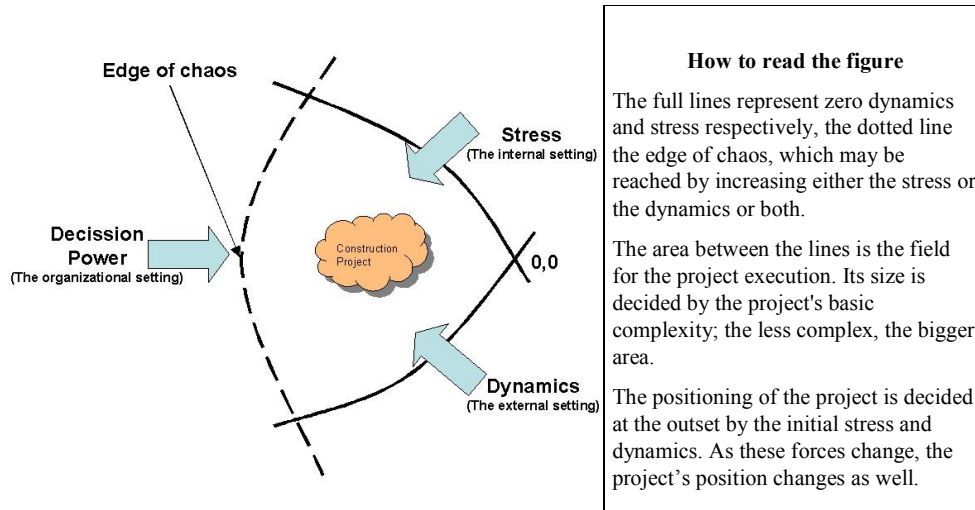


Figure 1: The project's balance between the forces

Keeping the system in the ordered region requires either a reduction of its dynamics and stress or an increase of the decision power or both.

THOUGHTS ON THE PRACTICAL USE OF THE MODEL

Having modeled the forces the question arises: How should this be used in practice? From a project management point of view the value of the analyses grows tremendously if the approach can be used at the outset and during the course of the project to assess the risk of chaos and to point at measures to take in avoiding this risk.

UNDERSTANDING THE PROJECT'S NATURE

The starting point should be an analysis of the project's complexity. What kind of project are we dealing with, is it a simple and well known kind of building or is it a more complicated type, maybe even composed of several different construction systems? Also the familiarity of the construction process to the project organization should be considered.

The second step should be to estimate the project's external setting by looking at the uncertainty of the three constraints: directives, prerequisites and resources independently and

afterwards combining them using a thinking as symbolized by the formula outlined above. However, this should probably be done intuitively as a complex situation can not be expressed by linear functions. This gives us a sense of the project dynamics.

The next step is a similar estimate of the stress.

Finally comes estimating the decision power to keep the other factors under control. The firmer the decision power, the lesser the risk of the project moving over the edge.

Comparing the project's situation with other projects' may indicate how critical the actual project seems to be. It is not suggested that an absolute measurement should be aimed at, at least not until a great deal of experience is available. But a relative assessment should be possible for instance within the organization of a professional client or a design and build contractor.

The analyses should comprise a risk analysis as well. What are the risks of one or more of the factors changing radically for the worse and what could possibly release such a change? And, is it possible to establish a warning mechanism for such changes?

MANAGING CHAOS

The above analyses may make the participants much more familiar with the nature of the project, thus making it possible to discuss how to manage the complexity, dynamics and stress.

The first step may be to seek out the factors easiest to change in the right direction and then find out how far into the ordered regime this will bring the project's position. If this is not sufficient, other factors must be changed as well. The situation will probably often be that most or all the factors must be changed, i.e. complexity, dynamics and stress reduced at the same time as the decision power is increased.

The next step should be to organize the handling of dynamics and stress, in other word organizing the project management to deal with uncertainties. Last Planner seems a useful tool controlling chaos-in-the-small, but how to deal with chaos-in-the-large? Working with open options or alternatives and making and managing decisions at the last responsible moment combined with a formalized design freeze procedure should be considered. The isolation and absorption of uncertainty, as suggested by Laufer (1997), is one option. Further guidelines for handling various degrees of uncertainty may be adopted from de Meyer et al. (2002).

At the same time mechanisms to keep track of critical factors and issue warnings should be considered.

Finally, contingency plans and organizations should be considered. What should we do if ...? And, who should do it?

Comment: Would it be useful to locate what you're discussing (risk management?) within the context of the management model?

FURTHER WORK

The outlined method is, as far as the authors know, new and not tried out in construction practice even though most projects are judged in more or lesser detail along the lines outlined, not least the project's basic complexity.

However, it is the authors' opinion that systematic analyses of a number of projects may make it possible to establish a reasonable estimate of the risk of a given project entering a

chaotic state. The first step should thus be turning the outlined model into an operational set of methods and trying them out in practice.

At the same time similar analyses of executed projects, which have turned into a chaotic state should be made in order to better understand the nature of the phase transition. The characteristics of the chaotic state should be studied and its symptoms described. A challenge here may be that most contractors and clients want to forget all about a chaotic project once they have gotten rid of it, which may make such analyses hard to undertake.

At the same time tools for handling complex and dynamics projects under stress should be identified and brought into the model's terminology. This development should be supported by a deeper understanding of the working of loops in the construction process, to be achieved, for example, by means of general systems dynamics modeling (Williams et al. 1995).

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