Project Management in Chaos

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Abstract

Traditionally, project management (PM) has been seen as a stable and non-dynamic, linear process. By using traditional risk analysis, one will find only the most probable risks. In reality, the big risks that have never occurred before will remain unidentified. The traditional tools in projects are the Work Breakdown System (WBS) and network planning (PERT). A careful breakdown of a process is of no use if activities are unknown. The network approach does not approve of feedback loops. In addition, the correlations between the durations of activities are forgotten in both the planning and the risk analyses. The PERT or the risk analysis works if external disturbances, feedback loops, and internal correlations are ignored. However, they are not applicable in a state of chaos, on the edge of chaos, or in chaotic environments. Herein, the general chaos theory is applied to the context of project management and an attempt is made to design a new framework for managing versatile projects under unstable circumstances. Chaos in a project is defined as a state where project plans are updated or changed frequently and, moreover, no renewed plans are executed. Projects are potentially chaotic. Large stochastic simulations have been run in order to find out how to prevent the consequences of randomly varying durations, interdependences and correlations, feedback loops and the effect of unknown activities. The results of the simulations are presented in this paper. Some measures have been developed to keep a complex project (operations) on the edge of chaos. One should cut any feedback by using paced project planning, make the WBS independent through separate resources, prevent external effects by using partnerships, and set up an open grass-root communication system.

Keywords: Chaos theory, construction, project management, simulations

1. Introduction

In the 1990s, chaos theory was applied by many scholars in attempt to understand the organizations' ways of operating in extremely dynamic environments. In this paper, chaos theory is applied primarily to the context of project management. Traditionally, project management has been seen as a fairly stable and non-dynamic, linear process (see PMBOK, for instance). A part of traditional project management is risk management: risk identification, risk estimation (probability and consequences), risk response, and risk control. The requirement to estimate the probabilities of all indentified risks implies that traditional risk management is useless in a state of chaos. **Traditional risk management** does not provide us with answers in chaotic and unstable environments. By running this risk analysis, one usually find only the most probable risks coupled with small consequences, and organizations mainly plan their responses to deal with these kinds of risks. In reality, those risks that have big consequences and which have never occurred before remain unidentified.

In turn, **chaos** is a deterministic, non-linear, dynamic, fractal system that produces results which appear to be random. In a state of chaos, a system remains in a restricted area, but it has no equilibrium. In a chaotic system there are several factors, dependencies between these and feedback loops. Changes are irreversible. This description suits organizations well with inherent interdependent feedback forces. The well-known butterfly effect suggests that a chaotic system is sensitively dependent on its original state (and thereby also sensitively dependent on any of its states). In particular, the behavior of project management organizations has traits of vulnerability. In bifurcation, the state of a system is suddenly split into two states. Consecutive bifurcations create chaos. Organizations change due to bifurcation. Development paths are unpredictable. An attractor is a state to which a system strives to re-establish. We are familiar with the habits of organizations to revert back to 'the old way' of doing things despite management's efforts to make changes. Chaotic organizations have so-called "strange" attractors (or states), that they try to achieve. Herein, the term chaos is used quite freely to mean 'uncertainty' and 'instability' as opposed to stable conditions.

The rationale of the paper is as follows. First, chaos is dealt with in both the case of managing an organization and a project. Second, the results of four large simulations are reported on. Third, an attempt is made in order to design a framework for managing versatile projects under unstable circumstances. The reasons for the authors interest in managing projects in chaos stem from the turbulent and unpredictable construction conditions in Russia. Finally, the validity and the consequences of the proposed framework for advancing construction project management are discussed.

2. Chaos within an Organization

Thiertart and Forgues (1995 [1]) have presented **the following hypotheses** about organizations and chaos:

- Organizations are potentially chaotic due to feedback.
- A change from a stable organization to one in chaos happens unnoticed.
- In a state of chaos, small changes may have unpredictably big consequences
- In a state of chaos, new "strange" organizations are created on any level or process.
- The same action leads to a different result in different organizations and at different times.

The more actors, feedback forces, and different time spans of action an organization has, the greater the chance it ends up in chaos. An organization is always in one of three states, i.e. a stable state, moving in a periodically stable state, or in chaos. The moving state is called **the edge of chaos**. Organizations move from one state to another with consecutive bifurcations; i.e. by splitting in two parts. In a chaotic state, the long-term effects of a change are unpredictable. Identical measures within the same organization at different times lead to different results.

A chaotic organization constantly approaches strange forms. A chaotic organizational and process form has a fractal structure. A given chaotic organizational and process forms can be found at the corporate, department, and team levels.

The principles for keeping the operations of an organization on the edge of chaos consists of [2]:

- advancing with small steps and making short term decisions (trying to make a non-linear system linear),
- keeping simultaneously a track-record on what's happening at all levels of the organization and within all its processes,
- trying to detect the first bifurcation at any level or within any process; quickly expanding, and changing immediately your actions according to the perceived consequences.

In a chaotic environment, mere experience is not enough because repeating the same action that worked before does not necessarily result in the same outcome in a subsequent situation.

3. Chaos within a Project

Chaos in a project is a state where project plans are updated or changed frequently, and moreover no renewed plans are executed. Herein, the hypotheses of Thiertart and Forgues [1] are applied to a project as follows:

- Projects are potentially chaotic.
- The more parties involved and the longer the project, the more potentially chaotic it is.
- A project is always in either a stable or chaotic state.
- A change in relations between two or more variables may cause a project to move from a stable state into a state of chaos.
- The consequences of changes taking place in a chaotic project are impossible to predict.
- In a chaotic state, identical actions taken in the same or different project do not lead to the same results.

Internal chaos occurs when its source is one (more) of a project's own actors. When the objectives of an owner, users, or their needs change, disturbances emerge in financing and, thus, keep project plans in flux. On the one hand, poor project planning or control may also be a source of chaos or project planning and control would be means of controlling internal chaos.

External chaos is created by factors that are beyond the influence of the organization. An organization operates in an environment where changes are created, i.e. laws and the regulations of authorities change, deliveries are late, and the loyalty of employees is lost. Business environment seems to be chaotic if one does not understand the way it works. Thereby, the environment and the behavior of people in a foreign culture may seem to be chaotic to an expatriate, even if locals understand it well. There are no chaotic environments – just ignorance about the environment. External human chaos is thus prevented by a better understanding of the environment and the culture.

Chaos takes place in a project, when project control spots **non-planned events** such as (for instance):

- activities change and evolve,
- new activities are created and original ones are not executed,
- activities have to be carried out all over again,
- activities are not finished and everything remains incomplete or almost ready,
- there is a positive correlation between durations of activities,
- new interdependencies suddenly appear and external dependencies occur unexpectedly.

As a result, the objectives of the project are not met, timing fails, and costs get out of hand.

The traditional literature on project management emphasizes what should be done: plan, control, and make corrective actions. In a state of chaos, it is more important to have a general understanding **how to handle the situation** than what to do. Chaos is usually caused by people, not forces of nature, so the key questions should be: who, how, where and when – not what. For preventing chaos, one should thereby ask **WHY things can go wrong**, not WHAT can go wrong? This means that one should understand the mindsets and goals of the project participants as well as the environment and culture in which one operates. This may require an “adapter” (“facilitator”), a cultural interpreter.

4. Why Does Traditional PM Not Work in a State of Chaos?

In projects, a traditional tool of activity analysis is the Work Breakdown System (WBS) and the other tool for scheduling is the network planning technique (PERT). A careful breakdown of a process is of no use if activities within it are unknown, nor does the network approach approve feedback loops. In addition, correlations between activities are often not taken in account in planning and risk analyses. **The traditional PERT or the risk analysis** works if external disturbances, feedback loops, and internal correlations are ignored. In turn, neither works in a state of chaos or on the edge of chaos.

At the TKK/CEM, project scheduling has been simulated stochastically (Monte Carlo) in a number of ways during a long period of time as follows:

- Preventing consequences of randomly varying durations (Vehkaoja J., 1989 [3] ; Porkka-Aarnivuo S., 1989 [4])
- Preventing consequences of interdependencies and correlations (Simppa model) (Ristikartano P., 1994 [5])
- Preventing consequences of feedback loops (Ericsson H., 1999 [6]).
- Preventing a chaos state in complex construction project (ATOSim) (Ristikartano P. 2002 [7])

In these simulations, a feedback loop is described by a positive correlation between the durations of the activities. A positive correlation means that if the preceding task is late, the following task will take longer to perform as well. In a similar way, **project control** can be described by a negative correlation: if the preceding task is late, the duration of the following task will have to be made shorter.

Some key results of the TKK/CEM simulations are as follows.

(a) **In the context of project division, stages, and activities,** a project has to be cut into stages so that disturbances can be "squeezed into seams". Long peaceful activities that can be corrected should be preferred. Starting activities in intervals so activity planning can be done are preferred, and buffers are reserved at the end of the stages.

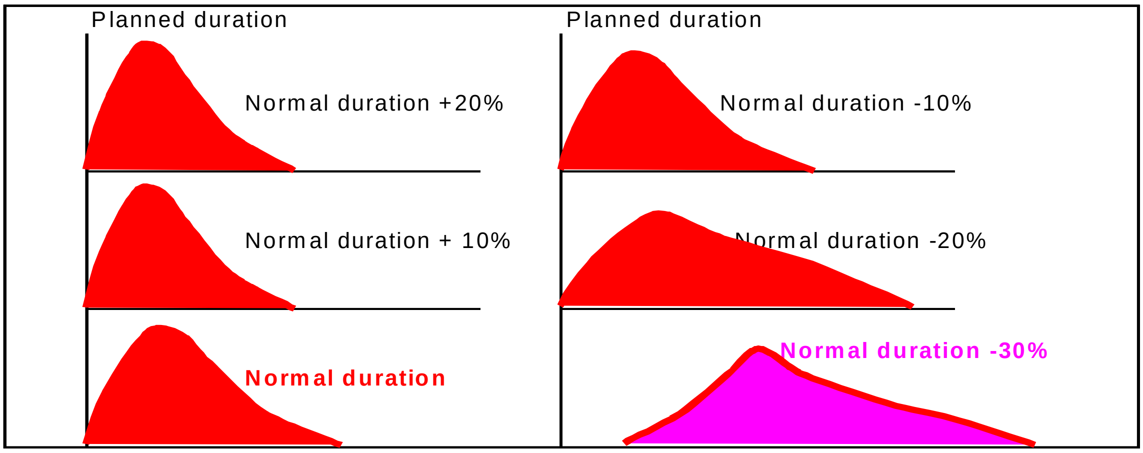

Figure 1: The distributions of the total durations when the schedule is extended or shortened. First chaotic features appear when shortening is 30%. (Vehkaoja 1989).

(b) **In the context of control, dependencies, and correlations**, even a small positive correlation leads to chaos, if control is not exercised, resulting in great variation. The use of the same resources for subsequent activities that cause positive correlations should be avoided. The control of workplaces is more efficient than control of the resources, and even a reasonable negative correlation, i.e. constant control is enough.

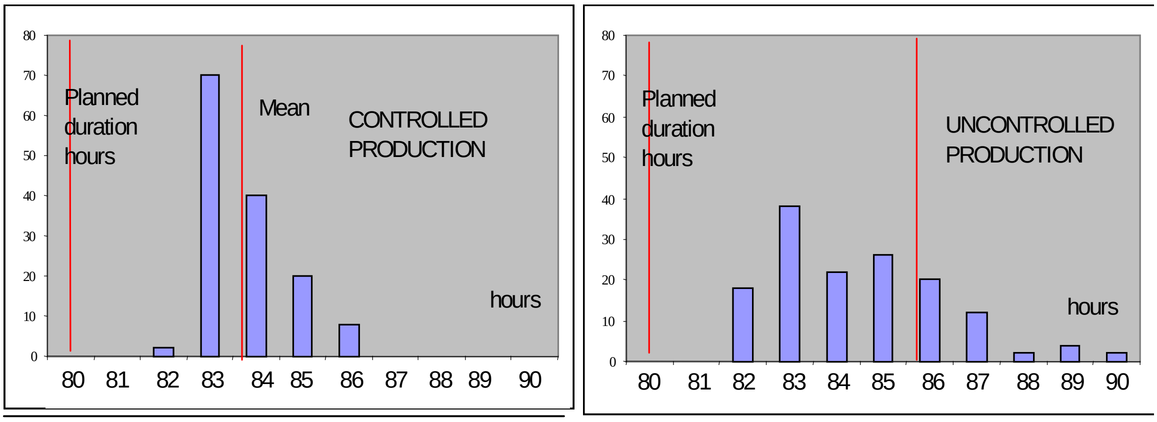

Figure 2: The distributions of the total durations (in hours) in the simulation of repetitive short throughput time (2 weeks) renovation of flats.(Ristikartano 1994). Control actions work well.

(c) **In the context of feedback and loops**, loops lead to bifurcations and spread out the duration of the project. Even if the probability of the loop is low, it will result in chaos and early signs of chaos are be seen as small trembles in durations.

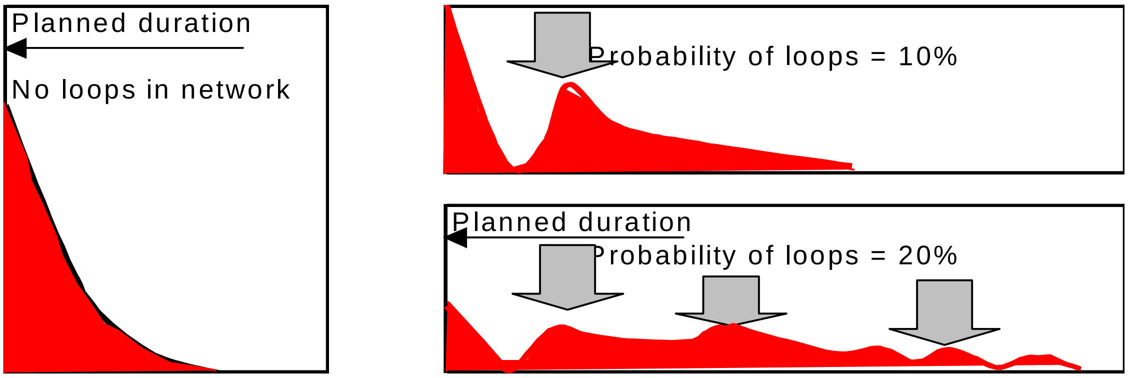

Figure 3: The distributions of the total durations in the simulation of the effect of loops in a schedule. If loops occur, the project is falling into a state of chaos.(Ericsson 1999).

Over the years, we have applied these results to practice when developing (among other things):

- A work sections technique for construction projects.
- A model of balanced schedules (advanced LOB) for construction projects.
- A model of short throughput times for repetitive projects.
- A staged execution model for a project in a chaotic environment.

5. Results of Advanced Schedule Chaos Simulator ATOSim 2002

The most recent research tool is called ATOSim from the year 2002 (Ristikartano [7]), **the advanced schedule simulator of the project.** The simulation model describes the effects of the duration variation and the starting disturbances of activities. Furthermore, it tries to capture also the effects of different control actions. With this model we have analyzed especially in what kind of conditions the project falls into a state of chaos and how the control can be used to repel the chaos.

The ATOSim model is based on the network technique and the Finnish place-time diagram (advanced LOB). The deterministic model consists of activities and their workplaces with durations, dependences between the activities, and external dependences. The statistic simulation factors of the model are the variation of the duration of activities, the probabilities and the duration of delays and the interruptions at the beginning of the activities, and the probability of the external dependences. As it is normal in the Monte Carlo simulations, the model gives the distribution of the total duration of the project as a result. During the research work, over 100.000 networks were calculated altogether.

In addition there are resource correlations between activities (the same resources are used). Control actions are described by the activity level and the project level. In the activity level control, the durations of activity in question is reduced. In the project level control, the durations of the remaining activities are changed. In the simulation, we tried different probabilities of internal and external disturbances, different schedule solutions, and different forces of control actions. The productivity disturbances were measured by the waiting time of resources.

Uncontrolled Production **Controlled production**

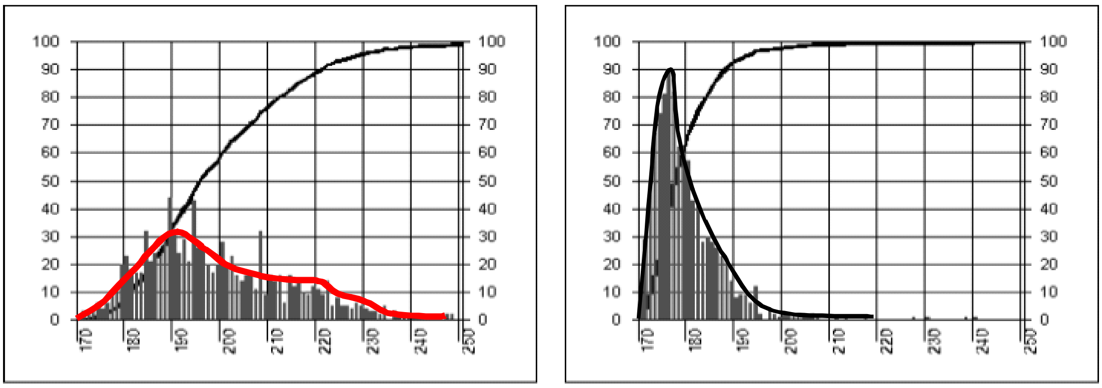

Figure 4: The distributions of the total durations in the simulation of the effects of the control actions. (Ristikartano 2002).

A probability of interruptions affects significantly the variation of the total duration. It does not depend upon whether it results from the late start of activities or from the external dependencies. The tight activity control degreases the variation. Continuous control actions have to be carried out. Productivity weakens rapidly when disturbances increase. Chaos is created when the probability of interruptions is high. Chaos is seen as both the lengthening and the large variation of the total duration, especially as the peak-less distribution of the duration.

In the schedules, the place of the buffer, the solutions of the critical activities, the number of the workplaces and the number of activities were varied. The buffers have to be placed at the end of the project or in the seams of the stages. However, the durations of tasks should be dimensioned tightly. There must be a lot of workplaces in the plan so the control has time to become effective. However, there should be fewer and bigger activities so that enough buffer time are obtained in the same total duration.

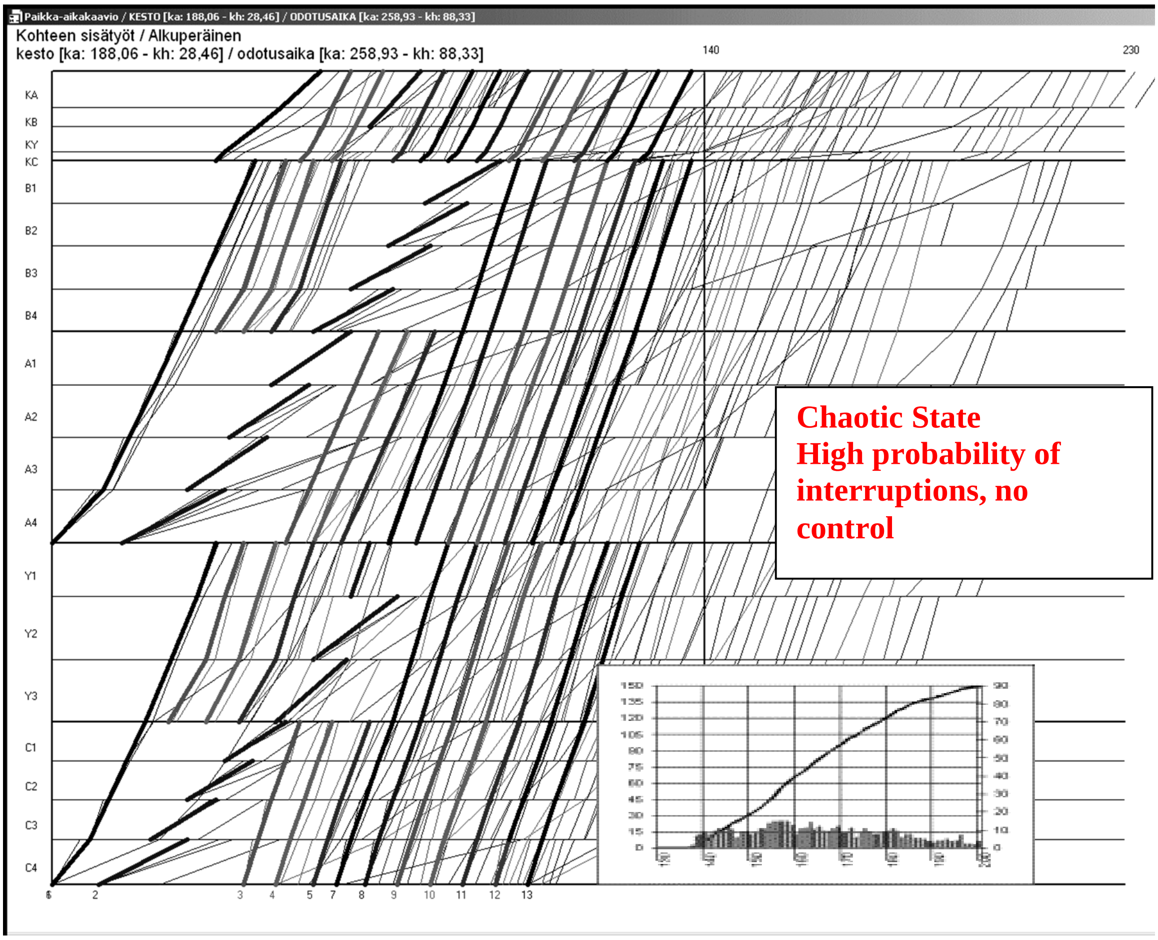

Figure 5: The place-time diagrams and distribution of the total duration in the simulation of the state of chaos. The thick lines are the planned schedule and the thin lines are the results of some simulation cycles. (Ristikartano 2002).

In the simulation model, the chaos is identified from the **form of the distribution,** which is nearly even (it does not show a clear peak). Furthermore, the clear growth of the waiting times is perceived. If the probability of a chaos is high, the production must be phased. In a workplace, the start of chaos can be repelled by isolating and condensing.

When **phasing** is used, the activities causing chaos are made ready before new activities are at all begun. In that case, the total duration is naturally prolonged considerably. When **isolating** is used, the resource dependencies are removed by using new crews and a workplace dependence is retained by preparing workplaces complete. In **sealing,** a workplace dependence is removed. This takes place by "jumping" over a workplace and moving the resources to the following workplace. The works of the "overjumped" place are then performed by separate resources (crew). When a probability of interruptions is high, it is not a big advantage to use balanced activities. It is then better to use the shipbuilding model in which "every workplace has separate resources".

6. How to Keep Your Project on the Edge of A Chaos

Herein, the initial framework for keeping a project on the edge of chaos is designed as **a set of rules for project management in chaos** as follows. In part, the generic rules are illustrated by the likely conditions in the Russian construction markets in the early 2000s.

1. Prevent feedback dependencies using project planning: Pace the project, divide it into stages and further into consecutive and independent activities. Divide the project into workplaces (production sections and areas). Interrupt the project immediately if a crisis takes place. Fix the problems of the preceding stage as a part of the next stage.

2. Make the WBS independent: Plan the work and procurement packages carefully with the proactive prevention of a chaotic state in mind. Packages should be independent from one another. All procurement packages, especially local or from a third country, should have pre-negotiated back-up contracts, respectively.

3. Prevent non-linearity by control: Control all the small tasks and on a short time span, change course immediately when needed. Have weekly meetings, make a special activity plan for each activity before its execution. Make pilots or models of new and difficult things beforehand.

4. Prevent the first bifurcation by ”fractal” control: Strive to detect the first weak signs of bifurcation. Exercise control of actual activities down at the site level. Control simultaneously all parties at all levels and in all processes. Act immediately when a problem is encountered. Do not put trust only in the compiled reports of the project as a whole.

5. Prevent external effects by using partnerships: Try to identify the influential stakeholders and enter proactive partnerships with them in advance. Align cultural differences by using cross-cultural and professional ”interpreters”. Use local designers for help. Listen to the local authorities.

6. Set up an open communication system: Create a fast, simple, and open communication system and test its performance constantly. Assume always that "they" do not understand. Coach and train your partners by a joint information system. Do not arrange academic lectures or teaching.

7. Support your goals with ”cultural” incentives: Clarify to other parties what outcomes you want the organization and the project to perform. Create rewards so that each culture accepts these as incentives for the joint realization of your goals. Try to support the egos of other decision makers, not your own.

Pacing the project squeezes chaos together. Chaos may occur in separate stages, but it does not move forward to the next stage. The results of a previous stage must be approved by all parties before the start of the next stage. Pacing causes longer total duration. This pacing procedure has been used in construction projects in Russia.

Non-linearity and a sensitive dependence of an initial stage are prevented by linearization, proceeding in small steps and, thus, making effects immediately known. In the suggested project management in a state of chaos, this means continuous planning and controlling instead of the traditional project planning before a start and reporting during it.

7. Conclusions

Herein, the validity and the consequences of the proposed framework for advancing (construction) project management are discussed as follows.

In these simulation studies, it was noticed that **schedules with different risk levels** can be made for the same project. The activities must be dimensioned right, they must be balanced. Especially, the whole schedule must be controllable. A tight control of the schedule reduces the risk of exceeding the scheduled duration and having a lot of waiting time. The control actions have to be made immediately and continuously. When more certainty is wanted, some **buffers** would be used. However, this extends the total duration of the project and increases costs.

At the beginning of a project, there are many possible completion dates. Different schedules can be made for the same project and the execution can be controlled in different ways. The schedule is fulfilled as such only if everything goes according to the plan. However, this does not happen in reality. The planned completion date is not necessarily even the most probable completion date. The Monte Carlo simulation can be used to test these alternative schedules. As a project proceeds, the disturbing factors are realized and they cause waiting time, the lengthening of the total duration, and the need for additional resources. In the worst scenario, a state of chaos is created which leads to repeated planning. The project reporting as typically found in textbooks does not help at all in a chaotic situation. All activities must be controlled from the grass-root level to avoid chaos.

To repel chaos, **an advanced planning system** [8] must be used in which the workplaces and the coarse general planning are combined, the detailed activity planning ís done just before the beginning of each activity, and a short time rolling window is used troughout the whole project. The corrections must be performed immediately. If work stops in one workplace, it should be jumped over immediately and a new team would be put in place.

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