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Organization of the Design-Construction Process

Organisation du processus du projet et de l'exécution

Organisation des Entwurfs- und Ausführungs-Prozesses

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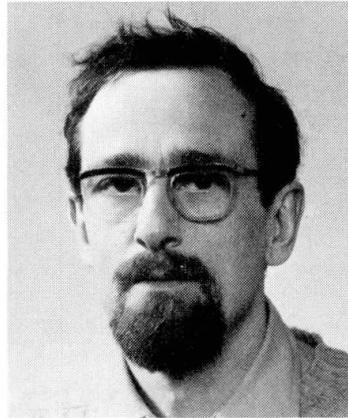
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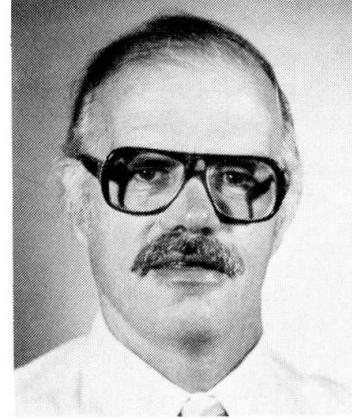
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SUMMARY

These introductory notes deal with organization and management of the design-construction process on a very general level. After a brief review of the evolution of safety analysis in structural engineering some elements of the present situation, alternative systems and motivation analysis are discussed. A number of interrelated questions are posed as a basis for discussion on a fundamental level.

RESUME

L'article présente d'une façon générale l'organisation et la gestion du processus de projet et de l'exécution. Après une revue de l'évolution de l'analyse de la sécurité des structures, il discute quelques éléments de la situation actuelle, de systèmes différents et traite de l'analyse de la motivation. Des questions sont proposées pour une discussion générale.

ZUSAMMENFASSUNG

Der vorliegende Bericht befasst sich mit Organisation und Management des Entwurfs- und Ausführungs-Prozesses in sehr allgemeiner Weise. Nach einem kurzen Blick auf die Entwicklung der Sicherheits-Analyse im konstruktiven Bauwesen werden einige Elemente der gegenwärtigen Situation, alternative Möglichkeiten und Fragen der Motivation erörtert. Eine Reihe miteinander verknüpfter Fragen wird gestellt als Basis für eine Diskussion auf grundsätzlicher Ebene.



1. INTRODUCTION

Earlier sessions in this workshop have dealt with several aspects of quality assurance in the design-construction process. Past and current experience with structural failures has been reviewed and primary causes of failure, including human error, have been described. The objectives of building have been formulated from several viewpoints and utility functions have been suggested in an effort to develop a logical framework for an optimal approach to design and construction control.

In this introductory note we will examine such aspects of the building process from an overall or macro point of view. To provide a background to discussion of construction organization, the evolution of concepts of structural safety within the profession will be reviewed. An understanding of this evolution and the present state-of-the-art is essential if the construction process is to be approached at an appropriate level of generality.

A major objective of this note is to develop a number of basic questions which the workshop may use as a basis for discussion. Attention will be focussed on private rather than government construction although most elements seem to be very similar in both situations.

2. EVOLUTION OF SAFETY CONCEPTS

2.1 The Traditional Concept

In spite of many painful experiences to the contrary, engineers have traditionally rejected the role of uncertainty in design. Using loads that could "never" be exceeded and strengths that were "guaranteed", buildings were made "absolutely safe". For generations, engineers relied on such an "it's true because I say it's true" philosophy.

This apparently absurd philosophy is actually quite sensible. It simply means that the engineer assumed personal responsibility for his decisions.

2.2 Rational Man - The Optimizer

To establish a rational basis for decision, the basic design components of load, analysis and resistance has been studied in great detail. Inevitably, a great deal of uncertainty in the various elements must be accepted and measured. Similarly, the relative importance of safety, time, and money must be established. Finally, we must define the context of safety decisions. Who is to make them? What are the boundary conditions?

Beginning with the work of Forsell in 1924, (2), numerous attempts have been made to formulate a "rational" approach to decision (3, 5). In these formulations, a "rational man" first lists all his alternatives and all possible future events. To each design alternative-future event combination he assigns a probability of occurrence and a measure of desirability. Decision follows automatically through maximization of expected benefits or utilities.

Because of the magnitude and variability of civil engineering works, subjective probabilities and values must be introduced to account for missing data and the nonmonetary costs of human life. By simple extension, one can consider



Absolute Safety

an hierarchy of decisions involving testing and evolving probabilities through Bayes' theorem.

The question "Who is to make the decisions with whose values?" once seemed relatively straightforward. Since most design is based on standard procedures, code committees were elected to decide, based on the values of "society".

It now seems that code committees can not normally be expected to be rational. Their primary function is to assemble experience and resolve conflicts between interested parties. When they do provide leadership, it is usually because of a dominant individual or group.

In spite of these problems, a rational man analysis does provide a reasonable model of ideal problems. In practice, decisions involve many personal and organizational constraints that are not considered.

2.3 Bounded Rationality - The Satisficer

To construct a more useful model of decision, the practical design process must be considered. The starting point must once again be an individual or small group, making decisions guided by codes and historical practices and, except for totally routine cases, assuming a certain responsibility for their actions.

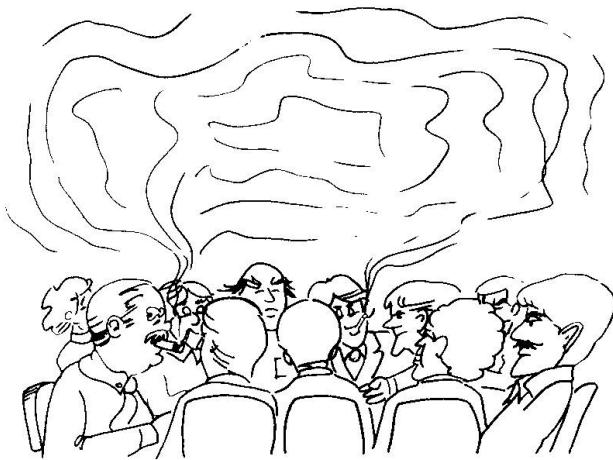
The practical decision maker differs from the classical rational man in several essential ways.

- (1) He does not list all feasible solutions but scans adjacent possibilities around an initial trial and stops when he has found a "satisfactory" solution.
- (2) His decision may change with time as a result of consultation with superiors, clients, contractors, material suppliers, and government officials.
- (3) He is under powerful organizational constraints in respect to his efficiency and practices. Substantial innovation implying significant risk may be contrary to his organization's or his own goals.
- (4) He has limited control of the total construction process and has limited responsibility.

This decision maker will not normally seek to optimize with the values of some abstract entity called "society". Instead, he will tend to act as what Simon has called a "Satisficer" (4).

The satisficer does not seek to optimize but rather looks for solutions which satisfy possibly conflicting constraints. To a large extent, decisions are imposed by the practices and objectives of organizations. The training of individuals plays a major role.

The satisficing concept helps to bridge the gap between a utopian rational solution and practical behavior. The global design experiment can thus be



The Code Committee



viewed as an incremental satisficing evolution. Unfortunately, a satisficing model is not normative in the sense that it suggests ideal behavior. It simply describes what we actually do in the face of complex uncertain situations.

The satisficing concept does, however, lead to one obvious fundamental qualitative conclusion. If a decision process and its results are to be changed, the attitudes and constraints of the decision makers must be altered.

2.4 Strategic Man

An interesting alternative "organic" approach to decision analysis has been suggested recently by Crozier and Friedberg (1), and others. In this view, individuals are considered as players in a set of complex games within organizations and between organizations. Both organizations and individuals are in constant flux, attempting to grow and increase their power and influence, constantly sensing the environment for opportunities and responding to hostile behavior.

This rather colorful image seems well suited to the construction industry. Material suppliers, unions, fabricators, contractors, governments, consultants and owners are in a constant state of evolution as competitive forces between materials, methods, and organizations are resolved. All elements of this system interact with society as a whole both as individuals and as a industry. For example, inadequate construction practices can lead to changes in government regulations, the decline of one component of the system, and growth in another.

A strategic view of construction may provide the theoretical basis for a major redefinition of the design process. Instead of viewing design as a game against natural hazards, an engineer can see himself as a player within a complex game where other players have other, conflicting, but equally rational objectives. With the best will in world, the construction game can be so badly structured that major problems are almost inevitable.



The Satisficer



The Construction Game

3. FIVE BASIC QUESTIONS

3.1 The Present Situation

From the perspective of this brief theoretical background, we can begin to evaluate the present situation. How, for example, should the profession react to press accounts featuring spectacular failures such as the Kansas City skywalks or bridge sections in New York? What are the implications of relatively frequent minor disasters involving collapsing formwork or veneers.

In related areas we must confront rather shocking statistics such as: "Jobsite accidents now cost the American construction industry \$8.9 billion a year". Injuries, fatalities and illnesses in construction occur at a rate said to be 54% higher than all other industries" ("Civil Engineering", ASCE, Sept. 1982). Recently, the costs of human error were estimated as 5% of the total cost of construction and no one challenged the estimate as unreasonable.

As a counterpoint, the results of a recent survey of senior executives in major property development corporations is of interest. Although the official objective of the interviews was to assess building owners' value systems with respect to serviceability failures, a great deal of unexpected information was obtained.

Although the opinions of each executive tended to depend on his background, general attitudes were evident in all cases. In particular, all agreed that structural design and construction were not major sources of concern. Problems could be avoided by careful selection of materials and the use of experienced consultants.

Most owners were very insensitive to structural costs. Compared to other sources of uncertainty such as heating and air conditioning, interest rates, tax considerations and the real estate market, structures themselves were a minor consideration. These opinions suggest that present quality assurance procedures for buildings are generally adequate, at least for the structure.

In spite of this note of optimism, nagging doubts as to the quality and trends in current construction continue within the profession. Somehow one feels that the repeated incidence of sway problems in tall buildings (The New York Times, October 24, 1982) is an important phenomena which we must move to prevent. The continued use of totally discredited details in masonry curtain walls, for example, does not seem acceptable.

As professionals we are legitimately concerned about such problems, but to ensure a realistic perspective we should perhaps ask ourselves the following question.

Question No. 1

By attempting to improve the construction process, are we not, in fact, trying to cure a healthy patient?

It may well be that the errors and mistakes we observe are simply the inevitable consequences of an evolutionary process and, like all such processes, essential for progress.

3.2 Systems of Design and Construction

Until fairly recently, the organizational structure of the civilian

building process was quite simple. A person or organization wishing to have a structure would commission an individual builder for both design and construction. Because building techniques were largely traditional and relevant crafts were well established, a single authoritative person could assume responsibility for the complete operation including supervision. Such a simple organization was prevalent as late as the nineteenth century, even for large projects such as Roebling's Brooklyn Bridge.

At some point the separation of design and construction began with architects and engineers emerging as separate professional groups between owners and builders. At about the same time, the state began to assume an explicit role in the building process through design codes, building codes and construction codes. Labor unions developed powerful positions which imposed serious constraints on the actions of others. As new techniques emerged, construction activities became more highly specialized. At least in North America, insurance, legal and financial agencies have assumed an ever expanding role in both pre and post construction.

In North America the present situation is extremely variable and in rapid evolution. Although design engineers and architects, contractors, and tradesmen are relatively tightly controlled by licensing authorities and labor agreements, economic pressures and competition generally are dominant. The relationship between time and money is uppermost in the minds of many people.

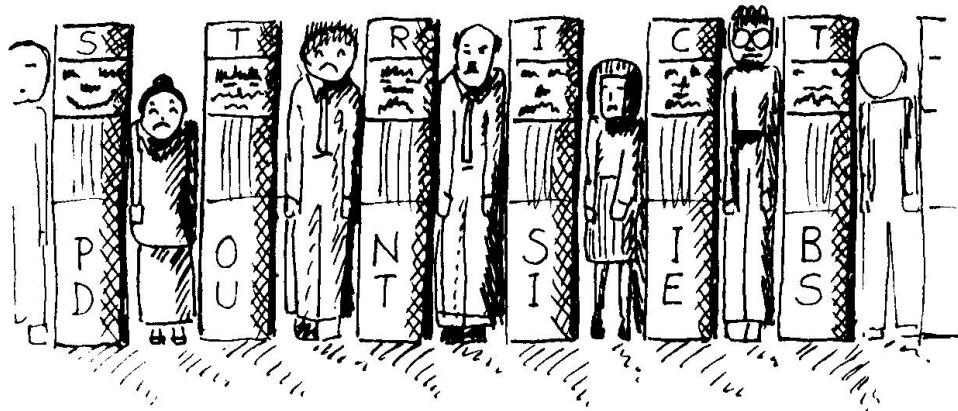
Responsibility for design usually lies with licensed engineers who are constrained by design codes. In the United States, these codes are developed by industry groups and adopted with or without amendment by local governments who generally have very limited technical competence. In most cases there is a number of alternative codes which have been developed by other groups and are consulted even though they may not be legally binding. It is unlikely that an engineer would be forgiven a serious blunder simply because a local code permitted it. Some cities require an independent design check for certain buildings but this is by no means a uniform practice.

In cities such as New York, general contractors who assume overall responsibility for a building have become a vanishing species. Not long ago general contractors began to subcontract almost all their work and so avoided, or at least diffused, responsibility for quality. To exert greater control, the construction manager has evolved as an agent of the owner, thus passing a great deal of responsibility back to the owner.

Owners have responded to this situation in various ways. Some have developed in-house design and construction groups while others have developed a short list of reliable people whom they use exclusively. Some have opted for turn-key operations, in effect returning to the traditional concept of a single builder.

Insurance companies in North America normally do not become directly involved in the building process although they do provide an educational service based on losses that occur in practice. Insurance rates are generally not related to the competence and reputation of the people involved in a building's design and construction.

The practice of "fast-tracking", where parts of a building are completed before other, interdependent parts have been designed, has also been adopted. The frame for at least one of the taller buildings in the world was well underway before wind tunnel tests had been completed.



TIGHTENING THE ORGANISATION

There are many cases where the process has performed very badly indeed. In one locally celebrated series of cases in Canada, architects combined the roles of part owners, designers, and general contractors for a set of speculative high-rise condominium apartments. With little construction supervision from the architects or building officials and the use of least cost subcontractors, the buildings were very badly built. The costs of repairs, which were extensive, were borne by subsequent owners.

No law was broken and no one could be held responsible in a legal sense. Such a failure may be called an "organizational failure" because the building process itself was fatally flawed. Since government authorities were unable to fulfill a protective role for budgetary and political reasons, the construction process was not sufficiently constrained legally. Everyone followed the human but unprofessional principle of maximizing his personal gain within the constraints.

In other countries, organization of the building process is very different. In France, for example, there is no legal constraint on designers but insurance companies play a major role in building quality control. Since these insurance companies are dominated by the government, there is in fact an indirect but very strong control of practice.

In Germany, a review of design is mandated by the State through the institution of the "Prufingenieur". Design itself is also rather rigidly controlled by comprehensive government norms.

From these observations it is quite clear that there is no consensus on how best to organize the building process. With this conclusion we can formulate two very general questions closely related to the first.

Question No. 2

Given the variety of forms and great complexity of the building process with many potentially conflicting participants, can we expect to improve quality without constraining or formalizing organization?

Question No. 3

If we tighten organization through definitions of tasks, roles, and responsibilities, do we not inevitably inhibit the natural evolution of the building process, including its self-healing capabilities?

In attempting to answer such questions we might be led to many subsidiary questions. For example, does the separation of the design and construction function in the hands of independent designers and contractors contribute more to quality of design than it contributes to error proneness through communication problems?

3.3 Motivation

Human beings are relatively complex organisms which respond to stimuli in many ways. According to one well known theory, they are motivated by an hierarchy of factors the first of which is the basic requirement for survival. Beyond this, people are motivated by a desire to be accepted by their peers and ultimately, if all other factors are satisfied, by the possibility of satisfying their own, usually high, image of themselves. This last factor is the dominant motivation of the artist who may accept a relatively low satisfaction level for more basic factors.

Attempts to improve the quality of construction tend to be founded in two basic types of assumptions concerning human behavior. The first assumes that man is essentially a risk and responsibility averter, seeking to maximize his personal gain while avoiding trouble and effort. Essentially, such a person assigns a high priority to the lower level of the motivation scale.

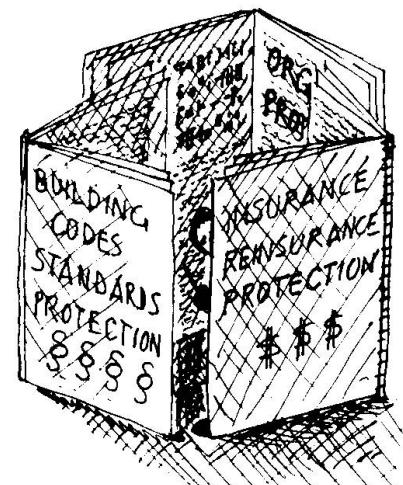
A second approach assumes that man is anxious to expand his capabilities, to assume ever greater responsibilities and to rise in the estimation of his peers. This assumption underlies appeals to professionalism, a sense of responsibility and "esprit de corps".

The first set of assumptions leads to strict regulation of the construction process and every actor in it. The second set leads to educational programs and relatively flexible control schemes. Some theoreticians assert that people will tend to behave as the system they inhabit expects them to.

Such questions of motivation enter into many discussions of construction organization. For example, our answers to the following questions will depend on our perception of the motivation of others:

Question No. 4

Given that the existence of insurance reduces an individual's exposure to risk from the consequences of his actions, is insurance not a disincentive to careful work?



BUILDER'S ARMOUR

Question No. 5

Since the use of established design codes generally protects a designer from many of the consequences of his actions while disregard of codes enhance designer liability, are codes not major obstacles to progress and improvement?

It would indeed be bizarre if the introduction of measures to protect individuals and the public should lead structural engineering into a sterile state of equilibrium where innovation is restricted, competence is not rewarded and repeated errors are accepted as routine.

An indication of the critical role of individual and organizational motivations is provided by the current U.S. controversy over nuclear power ("New Yorker", November 1, 1982). In an environment where large, powerful, private and government organizations were vying for growth and profit, technical assessments of risk were simply overwhelmed. Naive assumptions concerning the efficiency of individuals and equipment were accepted with the result that risk assessments were seriously underestimated. In several cases, warnings of potentially dangerous possibilities were ignored with near disastrous results.

Problems such as nuclear reactor policy are beyond the control of professional groups since they involve the complete economic and political systems of a society. However, the fact that an exceptionally tightly regulated design and construction process can produce disastrous results does suggest a limit to the value of formal constraints.

4. CONCLUDING REMARKS

In these introductory notes, we have attempted to take a "devil's advocate" view of several very general aspects of the building process. Our perspective was that of the process as a whole rather than an individual within the process. While this view is rather different than that of other introductory notes, it is not in conflict with them. Rather, our objectives were to broaden and generalize the problem so as to open new lines of thought and suggest limitations to the value of some approaches.

Consideration of organizational options cannot in itself lead to improved performance. Improvement must also be made through quality control in the micro-structure of individual design offices, material supply operations, and the many stages of construction itself.

However, by examining the overall construction process we may be able to identify particular organizational arrangements which tend to function exceptionally well or exceptionally poorly. At the moment we have no clear concept of the possible variants, no scientific data on their performance, and no scale for measuring their relative value. Although it is well known that organizational environment influences performance very strongly, we lack the basic tools to assess the effects.

Hopefully, some effort to understand the overall construction process, its communication links and responsibility flows will be made. Without such an understanding, many well intentioned innovations may result in failure.

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