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Autor: Turkstra, Carl J.

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Human and Organizational Aspects

Aspects humains et d'organisation

Menschliche und organisatorische Aspekte

Carl J. TURKSTRA
Prof. of Civil Eng.
Polytechnic Inst. of New York
Brooklyn, NY, USA

Carl Turkstra, born 1936, received his degree in Civil Engineering at Queens University in Canada. After completion of a Master's Degree at the University of Illinois, he received his Doctorate from the University of Waterloo in 1963. He is currently Professor and Head of the Department of Civil & Environmental Engineering at the Polytechnic Institute of New York.

SUMMARY
This report relates to organizational aspects of quality assurance in construction. Recent work on human error analysis is reviewed and some recent professional activities are discussed. Case studies are used to motivate discussion.

RÉSUMÉ
Le rapport traite d'aspects d'organisation en vue de l'assurance de la qualité dans la construction. Il passe en revue certaines études réalisées sur les erreurs humaines et quelques activités professionnelles récentes. Des études de cas sont présentées afin de susciter la discussion.

ZUSAMMENFASSUNG
Der vorliegende Bericht bezieht sich auf die organisatorischen Aspekte der Qualitätssicherung im Bauwesen. Neuere Arbeiten zur analytischen Erfassung menschlicher Fehler und einige Diskussionen innerhalb unseres Berufsstandes werden besprochen. Konkrete Fälle werden vorgestellt, um die Diskussion anzuregen.

1. INTRODUCTION

The theme of Session E, "Human and Organizational Aspects" is of particular relevance to current debates in construction. A number of international and national meetings have been held to discuss the issues involved and a series of major reports have been issued by professional, industrial and governmental organizations.

It is unusual for the civil engineering profession to find itself the focus of such public attention. The idea of a popular novel depicting "political skulduggery, bribery, murder and unthinkable catastrophe " surrounding the design of a tall building for example, is foreign to our conventional image (29). Headlines such as "Fast-tracking Blamed for Delays" are a shock to our ordered sense of reality (5).

During a speech at the New York Conference on the Infrastructure, Dr. Douglas Wright, President of the University of Waterloo made a number of points which are relevant to the question of quality in construction (35). Recalling the history of civil engineering, he pointed out the limitations inherent in a situation where "We see the world as something to be analyzed, and have perhaps lost sight of the nature of doing things successfully."

Dr. Wright pointed out the complex nature of reality. "We like to see the world as a problem to be solved; lawyers and politicians see it as a game to be played......We have to find ourselves less frequently victims of these processes."

In a discussion of the quality of construction we inevitably must go beyond the rational world of established procedures, mechanics and scientific models and enter the qualitative worlds of psychology, motivational theory, role analysis, conflict and information processes - a world in which the word theory can be used to describe a set of semantic relationships described by a series of boxes and arrows.

Nevertheless, this body of seemingly superficial knowledge is central to our task and can provide great insight and guidance. In many cases, the simple exercise of thinking and talking about abstract realities leads to enhanced common sense. Case studies revealing specific patterns of behavior now form the basic body of knowledge for legal and management studies and should be integrated into engineering thinking if we are to advance.

This report will examine several aspects of both realities - the scientific and the non-scientific. A few cases of failure will be reviewed to suggest the importance of human factors. Attempts to model errors will be discussed and other current scientific research will be mentioned. Much of this material will be developed by other authors in this conference.

The objective of this preliminary paper is to establish a broad general schema within which a multitude of related hard and soft sciences can be linked.

2. CASE STUDIES

Recent major failures in the United States have led to a great deal of political and professional activity. A brief review of some of these failures indicates the complexity and nature of the problems involved.

2.1 A Ceiling Collapse

In 1983, a suspended plaster ceiling collapsed over a major pedestrian passageway killing 2 people and injuring 12 others. The ceiling was 10 years old. The owner is a major organization with an outstanding reputation for project quality and management strength.

Investigation revealed that the supporting wire ties were attached to light metal tabs in the metal decking of the overhead slab. The capacity of each tie was listed as 60 pounds on design drawings. Noone checked the design of the hangers and the usual practice for placing lightweight ceilings was followed by the ceiling contractors. Responsibilities were not clearly assigned with the decision on tie spacing left undefined and, by default, falling on a subcontractor. The ties were not adequate and are not now commonly used for plaster ceilings.

After the collapse it was discovered that many of the suspenders had failed previously, presumedly when workmen walked on the ceiling to work on mechanical equipment. Some ties were simply reconnected - in some cases doubling up on the tabs in the decking.

In 1982, during an inspection, the ceiling sagged abruptly. The following sequence of events is not entirely clear but the incident was eventually reported and found its way to the engineering office. The collapse occurred during an inspection before repair.

In reviewing the chain of events, we must ask why the initial tie failures were not reported. Were the people involved afraid to cause trouble by filing incident reports? Had a lack of experience with this kind of problem led to a false sense of security among the maintenance staff? Why did the warning path through to qualified engineering personnel not function properly.

Here we find a spectrum of causes from design error, inadequate assignment of responsibilities, inadequate maintenance information processing systems, inadequate training of personnel and an apparent problem with staff motivation.

2.2 The Skywalk Collapse

The celebrated collapse of walkways in a Kansas City hotel has been widely publicized. We now know that connections for the suspending rods were questionable as designed and incompletely detailed on original drawings. To cope with problems of "constructibility", connection details were changed to provide offset rods leading to the collapse (5).

Although the chain of events is unclear (the Judge commented "There are disclaimers of responsibility that let anybody blame everybody else") but certain events are of particular interest. Why was responsibility for detailing left floating between the primary designer, the fabricator and the fabricator's detailing subcontractor? (Organization? Motivation?) Why was there no serious engineering review of the adequacy of proposed changes? (Organization? Feedback? Responsibilities?) Why, in the stream of communications between interested parties, did no one recognize the critical nature of a single connector in a series type structure with obvious progressive collapse possibilities? (Education? Motivation? Organization?)

It is clear that the failure might not have occurred if the people involved had taken more time. The technology of the connections was not particularly advanced and a clear definition of responsibilities, feedback networks, checking procedures and documentation requirements have avoided the problem.

If nothing else, this case suggests that the telephone may be a very dangerous instrument.

2.3 WPPSS

At a recent workshop on construction quality a senior official reviewed the background to the cancellation of several nuclear reactors leading to the loss of billions of dollars by investors. This economic disaster (known affectionably as "whoops!") was a milestone in the U.S. nuclear industry and was said to have several basic causes. These included: - An ownership group with little experience in major projects. As a result, they became captives of their staffs and approved everything. - The nuke mystic which gave the project a magic aura leading to an absence of traditional constraints. - The Three Mile Island incident which occurred during construction. Decision processes were frozen out of fear. Change orders multiplied geometrically. - Public laws required separate tenders and fixed price contracts. This led to many prime contractors with very difficult liason and cascading change orders. (As someone asked, "Would you want your daughter to marry the lowest bidder?") There were hundreds of thousands of change orders since one change impacted many components of the system. - Banks provided unlimited credit. The projects were conceived and started during an energy crisis where the costs of energy were projected to rise without limit in an infinite market. Without financial constraints, there was little incentive for large organizations to control their efficiency and costs of operation.

Although no structural failure occurred, this project was a major disaster.

3. QUANTITATIVE ANALYSIS

Realization of the central importance of data on real failures and their control within academic and professional circles has led to a number of studies of considerable importance. Those which follow scientific methods can be reviewed in two categories.

3.1 Data Base Development

The first series of scientific questions to be answered are of the form: what are the causes of failure in practice? What is their nature and what are the conditions leading to their occurence?

One of the first large scale studies of failures was made by Matousek and Schneider (20,21). In this study, 800 failures were investigated and classified according to the phase of the building process in which they occurred, the category of materials involved and the nature of the error causing the failure. It was found that most failures were not associated with design conditions but rather with human errors and flaws in the building process.

Another extensive survey of structural failures on buildings was reported in a symposium in London in 1980 (15). Major conclusions involve the need for qualified personnel, the importance of interface problems and communications, the danger of reliance on standard procedures, and the need for continuity of responsibility during the design and construction processes.

Another, more recent study was presented at the Rigi Workshop on Quality Assurance by Melchers, Baker and Moses (23). Failure data taken from the literature was analyzed to establish the relative incidence of failure modes, age at failure, prime causes and the costs of failure. Once again it was established that failure is primarily linked to human behavior and competence.

Two recent Australian studies have provided exceptionally useful information on the attitudes and performance of engineers. The first, by Ingles (14), provides a statistical measure of the attitude of civil engineers to personal, professional and public risk,as well as insurance as functions of age and experience. The need to separate fatal and nonfatal risk and a pronounced professional aversion to fatal risk are shown.

In another study, Melchers and Harrington (24) have reported experimental results concerning the incidence of mistakes on basic design tasks under controlled conditions. Errors of various types in situations of varying complexity were investigated by means of questionnaires with standard problems. Although the number of responses was limited the results can best be described as remarkable.

As the academic field of construction engineering matures, an increasing number of relevant detailed studies are becoming available. For example, studies of the frequency and causes of work delay incidents are being made. In a study of EPA projects in the United States, Hester et. al. (10) related completion delay periods, construction administration costs, and general cost overruns to the use of six management techniques in design and construction. Results suggest very strongly that the use of formal and disciplined management policies and criteria lead to significantly improved schedule control and reduced costs.

In a related statistical study of construction claims, Hester (11) provides data suggesting why the traditional approach is not functioning well. In contrast to the assumptions underlying current practice, the risk of major changes during construction has increased significantly, and the owner, contractor and designer are increasingly drawn into joint development and shared responsibility. Violation of the basic assumptions underlying contract documents leads to tension and counter-productive behavior.

While statistical analysis does not in itself lead directly to useful conclusions, it does provide a basis for improved insight into the nature and causes of construction problems. In effect data provides a background for qualitative analysis in project management.

3.2 Error Modelling

3.2.1 Classical Models

Although it is now generally recognized that conventional reliability analysis does not systematically predict failure rate, procedures to account for human errors and other flaws in the building process have not been extensively developed. One of the earliest attempts to include human error in risk evaluation was made by Rackwitz (30) who modelled errors as discrete binary events. These concepts were extended to consider different classes of error and the effects of quality control procedures. Under appropriate assumptions, optimal checking strategies can be devised (31).

Lind (17,18) has considered the effects of discrete errors on safety index calculations and calculated failure probability as a function of the probability of error. An error elimination model assuming continuous checking was developed to permit evaluation of inspection policies. Melchers (25) developed similar models with extensions to account for the magnitude as well as the occurence of errors. Optimal checking strategies including Bayesian analysis were formulated. Nessim and Jordaan (26) developed similar analysis in the context of fault tree analysis.

Given appropriate assumptions concerning the nature, magnitude, and arrival characteristics of errors of various types as well as measures of the effectiveness of control procedures, the technology of risk assessment developed in the nuclear industry can be adapted. However, it is not certain that such approaches can be fruitfull given the highly individualistic nature of construction projects and the dynamic nature of real events.

In the United States, a major research study to model human error is being conducted by Novak and Carr. The study is intended to classify errors, to summarize relevant statistical data, develop safety models which predict the impact of errors on calculated values of the safety index, to perform sensitivity studies (27,28) and eventually to develop strategies for error control.

3.2.2 Fuzzy Models

The concept of "fuzzy" or imprecise numerical analysis has an intuitive appeal to engineers. In masonry design, for example, it is common practice to recognize only "inspected" and "uninspected" workmanship with no serious definition of either class. Questionnaires involving three or more discrete categories are commonplace. Given the limitations of classical reliability analysis and the vague and inprecise nature of many aspects of construction quality assurance, imprecise analysis would seem to be appropriate.

The first major effort to apply the logic of fuzzy sets to safety evaluation was made by Blockley (1,2). Starting with a list of factors relevant to safety, an evaluation scheme was devised to obtain a measure of error proneness for projects. Brown (3) and Yao (34) also discussed the use of fuzzy set theory in analyses. Furuta and Shiraishi (8,32) discussed general principles and applications in fault tree analysis. Fox (7) attempted a field application of the error proneness concept.

In spite of its intuitive appeal and the promise of the concept of "error proneness", applications of fuzzy set theory are limited and remain somewhat controversial (4).

4. QUALITATIVE ANALYSIS

4.1 Management Sciences

One of the obvious steps in quality assurance is to understand and use established concepts in management science. Questions of management structure, leadership, motivation, morale, group formation etc. have been studied extensively in other fields but have not been well developed in civil engineering (9,22). A research proposal to examine their application to error management was presented recently by Knoll (16).

At the center of any effort to reduce error, increase productivity and improve quality must be the problem of motivating individuals. Maslow (19) has suggested an hierarchy of factors ranging from satisfaction of physical and security needs, needs for social activity, needs for esteem and status and needs for self realization. In the modern construction industry, interest must focus on the higher needs for social grouping, esteem and personal pride.

There are many indications that existing legal and organizational constraints in the United States work against motivation for quality construction. Documents are formulated to separate rather than to reinforce cooperation. Documentation requirements can trivialize activities leading to low morale and diminished self image. Enhanced education and training increases motivation by raising confidence and instilling a sense of personal pride and auto-control.

The balance between regulation with punishment and freedom with personal rewards is especially difficult to attain in the construction industry which is characterized by strong personalities and relatively high risk. Perhaps, practices in eastern countries will contribute significantly to the resolution of these problems in the west.

4.2 Group Response

In response to public and professional concern over quality in the building process, a number of national and international workshops and study groups have been organized recently. In general the conclusions are not surprising but they do reinforce a realistic assessment of the situation and produce generic recommendations.

In the United States, Engineering Foundation conferences were held in November 1983 and January 1984. The most recent workshop on construction quality was held in Chicago in November 1984 (6). This workshop made a series of recommendations to the ASCE which include: - To prepare policy statements and publish a manual of Professional Practice for Quality in the Constructed Project, including sections on peer oversight project reviews and the clarification of project team members' responsibilities, authority and liability. - To develop guidelines, criteria and standards for evaluation of automated interfaces for information transfer between participants in the construction process. - To quantify measures and benefits of quality oriented planning, design and construction programs and promote learning and disseminating of lessons from performance - successes and failures.

A recent report entitled "Structural Failures in Public Facilities" by the House Committee on Science and Technology of the United States Government (12) came to the following conclusions: "The Subcommittee's review identified six significant factors (and several factors of lesser importance) which, in the opinion of the Subcommittee, contributed most significantly to the occurrence of structural failure. The six factors are: (1) communications and organization in the construction industry; (2) inspection of construction by the structural engineer; (3) general quality of design; (4) structural connection design details and shop drawings; (5) selection of architects and engineers; and (6) timely dissemination of technical data."

Somewhat earlier, the U.S. Army conveened a "Blue Ribbon Panel" to examine the problem of quality in construction. Responding to a general desire for less paperwork, lower costs and increased quality, the Panel found the present system to be basically sound but to have several serious problems. Within the context of this paper, the Panel noted serious morale problems among field staff due to a lack of responsiveness from engineering personnel. Among other things, quality was found to rank behind time and cost as driving forces in construction work. The Panel recommended: that quality be recognized as a primary goal at the highest level; that feedback systems on contractor performances be upgraded; that training in QA/QC be upgraded including cross-training of field and office personnel; and, that specific communication improvements be implemented.(33)

In Europe, the Rigi workshop on quality assurance provided an unusual forum for discussion among international authorities in various disciplines.(13) The conference identified many basic elements of the problem in the soft sciences of psychology and sociology as well as the harder sciences of hazard analysis. Documentation requirements were discussed along with symbolic and detailed checklists for development of quality assurance plans.

5. FUTURE DIRECTIONS

It now seems that the basic problems in quality assurance have been identified with a clear consensus on the important issues - human factors, communication, appropriate documentation etc. Looking ahead, it seems that several useful lines of research and development will be followed. - development of automated information transfer and expert systems with intelligent checklists and feedback networks. - improved reliability models for evaluation of control procedures. The general concept of error proneness is particularly appealing. - data collection on human error, construction incidents and real human response to construction constraints. - integration of management concepts including motivation theory into project administration.

Engineers will continue to expand their horizons beyond the limited world of reproducible events to include human factors and an increased sensitivity to the legitimacy of other realities.

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