BNL-NUREG_44849

CONF-9010155--2

BNL-NUREG--44849

DE90 015127

AUG 06 1990

INFLUENCE OF ORGANIZATIONAL FACTORS ON SAFETY *

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There is a need for a better understanding of exactly how organizational and management factors at a nuclear power plant (NPP) affect plant safety performance, either directly or indirectly, and how these factors might be observed, measured, and evaluated. The purpose of this research project is to respond to that need by developing a general methodology for characterizing these organizational and management factors, systematically collecting information on their status and integrating that information into various types of evaluative activities. Research to date has included the development of the Nuclear Organization and Management Analysis Concept (NOMAC) of a NPP, the identification of key organizational and management factors, and the identification of the methods for systematically measuring and analyzing the influence of these factors on performance. Most recently, two field studies, one at a fossil fuel plant and the other at a NPP, were conducted using the developed methodology. Results are presented from both studies highlighting the acceptability, practicality, and usefulness of the methods used to assess the influence of various organizational and management factors including culture, communication, decision-making, standardization, and oversight.

INTRODUCTION

There has been an increasingly clear need to develop a means for examining and measuring the role of organizational and management activities at nuclear power plants with respect to their impact on performance reliability. The assessment of this organizational and management performance could be used in reliability assessments, regulatory oversight activities, performance indicator programs, and probabilistic risk assessments. The purpose of this research project, conducted for the United States Nuclear Regulatory Commission, Office of Regulatory Research, was to develop a systematic and objective methodology for assessing the influence of organizational and management factors at a NPP.

To achieve the objective of the research, a three-step process was used: (1) development of a descriptive concept of the human organization of a nuclear power plant; (2) identification of key organizational and management functions and processes related to safety performance; and (3) proposal of methods for the quantification of organizational and management factors.

DESCRIPTIVE CONCEPT OF THE HUMAN ORGANIZATION OF A NUCLEAR POWER PLANT

The primary purpose of this step was to develop an organizational concept of a NPP that would specifically describe those operational units that may exert a direct or indirect impact on safety performance. Several criteria were established for the concept: (1) the concept should be dynamic and process-oriented; i.e., should go beyond an organizational chart in that it should focus on functional relationships within the organization; (2) the concept should be empirically based and recognized in the scientific literature; and (3) the concept should be capable of reconfiguration under emergency or abnormal conditions.

The organizational literature is replete with theories of how organizations are structured. An extensive review of the literature uncovered a lucid and robust conceptualization of this material by Mintzberg (1979). After assimilating the literature, both empirical and theoretical, Mintzberg provides a model to define the basic types of organizational structures and the associated variables that are characteristic of each type. A detailed discussion of the Mintzberg model as it relates to the objective of this research project is provided by Haber et al. (1988).

Using the model provided by Mintzberg (1979), the NPP can be described by a particular organizational structure. The organizational units and their function, and the specific characteristics that depict work flow in the NPP have been discussed in detail elsewhere (Haber et al., 1988). In summary, the NPP, at least initially, is best described by Mintzberg's "machine bureaucracy" and depicted in Figure 1. An important functional unit in this type of structure is the technostructure which is primarily responsible for standardizing the work within the organization. Standardization is a primary coordinating mechanism for work in the NPP and is carried out by departments such as licensing, training, quality assurance, planning and scheduling, and engineering. In addition, the NPP is vertically centralized, with decision-making occurring primarily from the top down, and work units within the organization are grouped by function (e.g., maintenance, operations, instrumentation and control).

*Work performed under the auspices of the U.S. Nuclear Regulatory Commission.

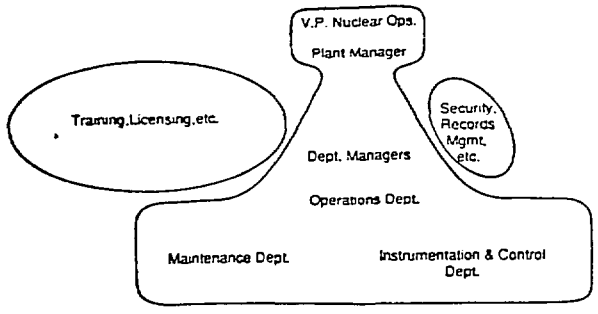


Figure 1. Organizational Concept of a NPP

IDENTIFICATION OF KEY ORGANIZATIONAL AND MANAGEMENT FUNCTIONS AND PROCESSES

If the NPP is best described by the "machine bureaucracy" organizational type, then a primary process of the organization is the standardization of work. The key organizational and management functions can then be identified in terms of the subprocesses of standardization; design of standards (including procedures for hardware and software components of the plant), the application of standards (the conveyance to personnel performing the work which is involved), the feedback on standards (communication and education of refinements to modify the standards), and the override of standards (modification in the event of abnormal conditions) (Haber and O'Brien, 1988).

The initiation of standards for the organization is primarily performed by the strategic apex, the functional unit responsible for ensuring that the organization serves its mission in an effective way. The development of standards occurs largely within the technostructure of the organization. Supervisors and managers within this organizational unit are critical in developing the policies and procedures comprising the standardization process. Middle line supervisors and managers are responsible for interpreting the standards and the supervisors of the operating core (those individuals actually performing the work within the organization) ensure implementation of the standards. Feedback for modifications to the standards should occur across all components of the organization through these supervisory and management functions.

The organizational concept of the NPP described above has been labeled the Nuclear Organization and Management Analysis Concept (NOMAC). The basic utility of the concept lies in its description of the human organization of a NPP and that it is a dynamic, interactive, and behavior-oriented characterization of the plant, emphasizing functional relationships between units. The identification of such a concept allows ideas generated by a particular characterization of the organization, in this case, a "machine bureaucracy," to be hypothesized and subsequently, tested by the proposed methodology. The "hypotheses" generated by the concept also allows comparisons to be made between and within facilities with regard to organizational characteristics and management functions.

QUANTIFICATION METHODS FOR MEASURING ORGANIZATIONAL AND MANAGEMENT FACTORS

In order to assess and evaluate NPPs with regard to organizational and management factors, three specific types of data collection were proposed. The first, a functional analysis, provides a description of the organizational work flow obtained primarily through interviews, documentation, and the observation of organizational activities such as meetings. Key personnel within the different organizational units are also identified. This method provides a good qualitative description of the organization as well as allowing allocation of resources for additional data collection.

The second method proposed is the use of a standardized questionnaire to assess the organizational culture/environment of the NPP. The questionnaire can be administered in group settings to all levels within the organization. In particular, the questionnaire includes the Organizational Culture Inventory (Human Synergistics, 1987) which has been used across many different types of organizations. Additional scales are also included in the questionnaire measuring safety culture, hazard, cohesion, communication, and job satisfaction.

The third method proposed is an observational technique. This technique assesses the frequency of management behaviors as well as identifies the patterns of communication and interactions within the organization. A standardized taxonomy of organizational and management behaviors was developed, modified from the work of Komaki et al. (1986). Based upon the functional analysis described earlier, selected supervisors and managers are observed during their workday. Trained observers follow the individuals selected around and record behaviors from the taxonomy. Each observation consists of 30 minutes and is conducted at different times of the day. The number of observation periods and individuals to be observed is dependent upon the organization being studied. The technique and taxonomy used in the NPP is described in detail elsewhere (Haber et al., in press).

DEMONSTRATION STUDIES

Two field studies, one at a fossil fuel plant and the other at a nuclear power plant, were conducted using the proposed methodology. Both of these studies were done in collaboration with a research group from the University of California at Berkeley interested in the beha-

vior of "high reliability" organizations. These demonstration studies were used to assess the practicality, acceptability, and usefulness of the NOMAC methodology. The intent in this stage of technology development was not to evaluate the organization and management of the field study sites, but to test the validity of our organizational concept and the methods proposed to quantify this description. Criteria for the demonstration studies included the appropriateness of the methods proposed for the validation of NOMAC, whether or not the results obtained could be standardized across facilities, the reaction and comprehension on the part of the facility management and staff to the methods, the operability of the methods, the resources required, and the quantitative application of the data collected for the objectives of the research.

Fossil Fuel Plant Demonstration Study

The NOMAC methodology was first implemented at the fossil fuel plant. A functional analysis, observational technique, and survey administration was conducted as described above. Although NOMAC could not be validated in a non-nuclear organization, valuable lessons were learned in implementing the methods.

The functional analysis was completed without any major modifications. It provided the qualitative description of the organization necessary to understand the work flow and functional relationships within the plant. Identification of key managers and supervisors yielded a list of 18 individuals identified for the observational technique.

The survey administration was conducted in cooperation with facility management. Group administrations were scheduled and a total of 179 questionnaires were completed and analyzed. The individuals surveyed were from the operations, maintenance, and engineering departments and represented approximately 64 percent of the total plant population. Statistically significant differences between departments at the plant were obtained on several of the Organizational Culture Inventory scales as well as on the communications scales. Differences were also obtained between managers and non-managers on many of the scales. A detailed description of these results is presented in Haber et al., in press.

The most valuable information from the fossil fuel plant study were the lessons learned concerning the observational technique. Based on the criteria discussed earlier: (1) the usefulness of this method for NOMAC was limited with the behavioral taxonomy used by Komaki et al. (1986). Behavioral categories more focussed on the NOMAC "hypotheses" were developed for use of the observational technique at a NPP. Additionally, the unit of analysis was changed from Komaki's use of duration of behavior to frequency; (2) for practical purposes, the number of trained observers to be used in the next study was reduced; and (3) the acceptability of this technique was very positive. Facility management and staff adapted to the observers' presence rather quickly and on only one occasion were observers asked to leave because of the personal nature of a conversation. In general, what the method intends to measure is useful, but the particular behaviors to be observed and how they were to be measured were modified for their application at a NPP.

Nuclear Power Plant Demonstration Study

Subsequent to the modifications from the fossil fuel plant demonstration study, a second implementation of the NOMAC methodology was conducted at a nuclear power plant. This demonstration study allowed an examination of NOMAC as well as the modified methods.

The first method implemented in this study was the functional analysis. Interviews were conducted with upper management, organizational documentation was reviewed, and observations of certain organizational activities (e.g., meetings) were made.

As in the fossil fuel plant demonstration study, the functional analysis provided a good description of the human organization of the nuclear power plant. Several "hypotheses" from NOMAC were also addressed. Consistent with the idea formulated in NOMAC, the influence of standardization of work in this NPP is very pervasive; a case in point is the development, implementation, and use of a management information system which drives a tremendous amount of the work in the plant; the nature of decision-making in this NPP is sometimes collegial and not always vertically centralized. This represented a slight departure from the vertical centralization described by NOMAC. Finally, the functional analysis also helped to identify the key supervisors and managers for the observation technique.

As discussed above, the behavioral categories used in the observational technique were significantly modified for this demonstration study. The new taxonomy consisted of 37 behaviors and permitted the measurement of communication processes, the mode of communication as well as the identification of whom the communication was with. With this new taxonomy, and a reduced number of trained observers, an inter-rater reliability of over 80 percent was achieved prior to the collection of data with this method. Twenty-two supervisors/managers were identified to be observed. Each supervisor/manager was observed for 10 periods of 30 minutes each.

The new taxonomy of organizational and management behaviors developed for this demonstration study was found to be very useful. Very little was observed during the course of the observations that could not be described by the behaviors in the taxonomy. In addition, differences were obtained among individuals on several of the behaviors. Behaviors and communication variables were measured by the frequency of occurrence as well as with whom they occurred. For the purpose of analyses, the taxonomy of 37 behaviors was grouped into six broader categories: decision-making (DM), planning and organizing (PAO), management attention and oversight (MAO), clarifying ambiguity (CA), solitary work (SW), and non-work related activity (NWR). (For a more detailed description of the behavioral taxonomy, see Haber et al., in press).

Table 1 represents an example of the results obtained from the observational technique. Specifically, the directionality of interactions across organizational units in the NPP is described in this table. Two main points relevant to NOMAC are demonstrated by these results: (1) the middle line spends the majority of its interactions with the operating core and the technostructure. NOMAC describes a key management function of the middle line to be in the interpretation of standards which would require it to be the liaison between the developer of standards, the technostructure, and the implementer of standards, the operating core; (2) the strategic apex spends the majority of its interactions with the middle line. As the initiator of standards in a primarily vertically centralized organization, the strategic apex must communicate its direction to the middle line for its role as interpreter of standards and as the chain of authority between the strategic apex and the operating core.

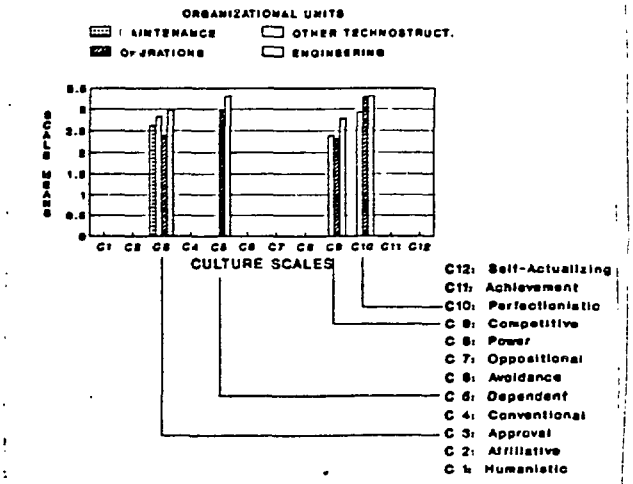
Table 1. Directionality of Interactions in a NPP

		RESPONDENT ORGANIZATIONAL UNIT					
ORG. UNIT	N[1]	OC	TS	SPRT.	ML	SA	EXT.
Operating Core (OC)	1131	74.6[2]	13.2	2.9	4.2	0.5	4.6
Techno-structure (TS)	638	11.2	59.2	2.3	2.0	6.2	19.1
Middle Line (ML)	354	39.5	32.2	8.5	11.3	16.1	4.2
Strategic Apex (SA)	638	13.0	14.4	6.2	34.0	11.9	18.5

[1] N = Total number of interactions observed.
[2] Numbers represent percentages of total interactions observed.

The third method, the survey administration, was self-administered in the nuclear power plant demonstration study. The response rate, however, was excellent at 84 percent (516/615 distributed). Several scales were included in the questionnaire, the Organizational Culture Inventory (OCI) which consists of 12 cultural scales, and commitment, cohesion, hazard, safety, routinization, job satisfaction, interdependence, and coordination scales.

A good representation of organizational units were sampled in the survey administration. Several of the scales did yield significant differences among departments, as well as differences between managers and non-managers. The use of NOMAC organizational units was also useful in discriminating among groups within the plant. Figure 2 depicts organizational unit differences on four of the OCI cultural scales. The engineering group was significantly different from some of the other groups on the approval, dependent, competitive, and perfectionistic OCI scales. (For a detailed explanation of these results, see Haber et al., in press.)



SCALE RANGE: 1 (low) - 5 (high)

Figure 2. Statistically significant differences on OCI scales among organizational units

An interesting result obtained from the survey administration pertains to safety culture. Departments within the NPP perceive their jobs as differentially hazardous (Figure 3). Despite these statistically significant differences, no differences were obtained across any of the departments or organizational levels on the safety scale. The overall mean score for the NPP on the safety scale was high, indicating a homogeneously high regard for attention to safety in this plant. Additional differences were obtained on some of the other scales and are discussed in Haber et al., in press.

Key Organizational and Management Factors

From the results obtained in the two demonstration studies, in particular their validation of some of the NOMAC "hypotheses", key organizational and management factors can be identified for further validation and investigation. These factors include the processes of

standardization, decision-making, communication, management attention and oversight, and organizational culture. Variation seems to exist on these factors across organizational units and levels, and they correspond to what has been discussed in the literature and described by NOMAC.

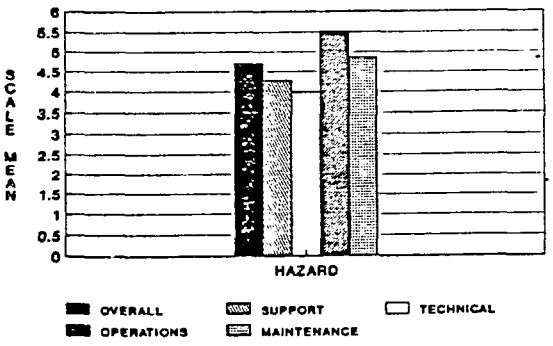


Figure 3. Statistically significant differences among departments on hazard scale

SUMMARY

The results from the two field studies demonstrated that the proposed NOMAC methodology can be successfully implemented in a nuclear power plant. Differences observed in terms of behaviors, patterns of communication and interaction, and organizational culture were related to the structural and functional positions within the plant. The differences are also generally consistent with "hypotheses" derived from NOMAC. The methodology was acceptable to plant management and staff and provided feedback to them concerning important organizational and management behaviors.

Research to date in this project has included the development of NOMAC, the identification of key organizational and management factors, the identification of the methods for systematically measuring and analyzing the influence of these factors and the demonstration of the implementation of the methodology. Future work will most likely include continued refinement of methods for increased validity in these types of organizations, increased data collection for use in more quantitative and comparative applications, integration of these methods into evaluation and assessment processes, and the continued development of a process for integrating organization and management data into risk assessment for human error.

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