MODEL DEVELOPMENT FOR THE DETERMINATION OF THE INFLUENCE OF MANAGEMENT ON PLANT RISK*

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Abstract

This paper outlines the development of an organizational model which will be used to determine the influence of supervisory and management functions in a nuclear power plant (NPP) on risk. A theoretical conceptualization, derived from the empirical literature, is used to describe the organizational structure of NPPs. The parameters and variables associated with this dynamic, process-oriented model are detailed. Applications of the model and preliminary insights derived from this conceptualization are discussed.

Introduction

The purpose of this paper is to introduce the reader to a research project being conducted by Brookhaven National Laboratory for the Nuclear Regulatory Commission (NRC). The project is entitled, "Influence of Supervisor/Manager Factors on Performance Reliability." This paper discusses the purpose of the project, the development of an organizational model to be used throughout the project, and operational aspects of a plant necessary to identify the supervisory and management functions relative to performance reliability.

There has been an increasingly clear need to develop a means for examining and measuring the role of supervisory and management activities at NPPs relative to performance reliability. The assessment of this supervisory and management performance would be used in (1) reliability assessments, (2) resolution of Generic Issues (GIs), (3) regulatory oversight activities, e.g., Performance Indicator (PI) program, and (4) Probabilistic Risk Assessments (PRAs). In order to address this need, it is necessary to develop an understanding of how NPP-related supervisory and management functions can be observed, measured, and evaluated. The end result of this project must be a product useful to NRC personnel, NPP personnel, and PRA practitioners.

In order to achieve the purpose of this project, four tasks have been identified. The first task is to develop an organizational model of a nuclear power plant, specifically those operational units that may exert a direct or indirect impact on NPP safety performance. Next, the potentially key supervisory and management functions which may affect plant safety performance must be identified. The third task attempts to gain an understanding of the nature and direction of supervisory and management influences on personnel performance. Task 4 identifies approaches (methodologies) for analyzing and evaluating supervisory and management factors that may impact plant safety performance. Beyond the scope of these tasks is the utilization of the results obtained in reliability and risk studies. Only the development of the model to be used in the project (Task 1) will be addressed in this paper.

Model Development

The organizational literature is replete with models and theories of how organizations are structured. An extensive review of the literature uncovered a lucid and robust conceptualization of the material by Henry Mintzberg[1]. 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. Later work by Mintzberg [2,3] elaborates on the types of organizational structures elucidated by him [1], and incorporates new literature into the same basic conceptualizations.

A description of the variables which are addressed in the literature and the generic types of organizational models that have been identified are presented below. The conceptualizations and definitions are taken from Mintzberg[1] so that later discussion will be consistent in terminology and rationale.

Parts of an Organization

The structure of any organization is defined as the sum total of the ways in which it divides its labor into distinct tasks and then achieves coordination among them. Every organization has input and output. The output can be in the form of products or services. There are five basic parts to an organization which comprise its input. The personnel who perform basic work related to the production of products or services are identified as the operating core of the organization. These individuals could be the assemblers in an automobile factory, or the professors in an university, or the maintenance technicians in an NPP. The individuals charged with ensuring that the organization serves its mission in an effective way, and also serve the needs of those people who control or otherwise have power over the organization comprise the strategic apex. Examples are the president of a company, or the superintendent of a school system, or the plant manager of an NPP. Personnel who are a chain of authority between the strategic apex and the operating core are the middle line of the organization. Senior managers to first-line supervisors would fit into this category. Personnel who are responsible for and effect standardization within an organization are described as the technostructure. Depending upon the type of organization, accountants, trainers, or engineers would fit this description. Finally, the individuals who provide support to the organization outside the operating work flow are the support staff. Included in this group are the cafeteria employees, custodial staff, security, and payroll departments.

Mintzberg's conceptualization of the prototypical structure of an organization is presented in Figure 1. As the characteristics and parts of each organization

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PROTOTYPICAL MODEL COMPONENTS

from Mintzberg (1979)p.20.

Figure 1. Prototypical model components

become more or less prominent, the shape of the basic structure changes and defines another type. In order to understand the way these types take shape, a discussion of some of the variables associated with an organization follows.

Characteristics of an Organization

Coordinating Mechanisms

Coordinating mechanisms are the fundamental ways in which an organization coordinates its work. There are five basic coordinating mechanisms delineated by Mintzberg[1] and described below. When one individual is in charge of and responsible for the work of others, the mechanism is known as direct supervision. In the standardization of work, the contents of work for an individual are highly specified. Instructions provided to the consumer by a manufacturer to assemble a product are a good example of this mechanism. Similarly, standard operating procedures used in an NPP also represent standardization of work. The standardization of outputs mechanism standardizes the results of an individual's work in the dimensions of a product or the individual's performance in the case of services. A taxi driver has to arrive at a certain destination, but is not necessarily told which route to take to get there. When the type of training required to perform a certain type of work is specified, the mechanism is defined as the standardization of skills. Hospitals hire doctors from reputable medical schools to insure that they are properly trained to perform their job. The last mechanism identified for the coordination of work is mutual adjustment, which is the simple process of informal communication. This process is used in the simplest and also the most complex organizations.

Design Parameters

There are a number of parameters that can be viewed as defining certain characteristics of an organization. Job specialization defines work in terms of breadth and scope (horizontal specialization) and/or depth of job (vertical specialization). Horizontal job specialization refers to the concept of division of labor, while vertical job specialization relates to how

much control an individual has over their job. Training is the process by which job-related skills and knowledge are taught, usually outside of the organization. Indoctrination refers to the process by which organizational norms are acquired, or the socialization of the individual for the organization's benefit. Behavior within the organization is usually formalized in one of three ways: by a job description, by the work flow, or by a set of rules or policies within the organization. Grouping coordinates the work within the organization and can be done on the basis of (1) knowledge and skill, (2) work process and function, (3) time (e.g. shiftwork), (4) output, (5) type of client, or (6) geographical location. The two most typical means of grouping are by function and by output (market). The size of each unit within the organization often determines the type of coordinating mechanism used. Generally, the greater the standardization, the larger the size of the unit. Performance control systems and action planning systems allow the organization to plan its future and evaluate its present. The former regulates the results of a unit by setting objectives, budgets, operating plans, etc., while the latter sets specific actions and decisions for specified points in time. Organizations encourage communication outside formalized channels through liaison devices such as task forces and standing committees. Finally, if all the power in the organization is ultimately in the hands of one individual, the organization is said to be centralized. Centralization can occur both horizontally and vertically.

Contingency Factors

There are certain situations or states that are associated with the use of certain design parameters; these are called contingency factors. The age and size of an organization are two such factors integral to the development of structure. The degree of flexibility of the technical system can dictate a great deal about the structure of an organization. The environment outside of the organization as it relates to the work within the organization is a contingency factor. Power, including the presence of outside control on the organization and/or the personal needs of various members of the organization, is a critical factor in establishing structure.

Structural Configurations

Five "pure" types of structures are identified by Mintzberg[1] when various combinations of the characteristics and variables just described are considered. The simple structure has little or no technostructure and support staff, a loose division of labor, minimal differentiation among its units, and a small managerial hierarchy. A middle-sized retail store would fit this structure. The key part of the machine bureaucracy is the technostructure. There are large-sized units at the operating level, a functional basis for grouping, centralized power for decision-making, and a sharp distinction between line and staff. A national post office, steel company, or airline are organized in this configuration. A professional bureaucracy relies on the standardization of skills and training and indoctrination for work coordination. It has professionals for its operating core, and gives them considerable control over their work. This structure is common in universities, hospitals, and school systems. The diversified form differs from the others in that it is an overall structure superimposed on smaller structures. Each division in this configuration has its own structure held together by a central administrative group. Some of the largest corporations are organized in this configuration. Last, but not least, is the ad-hocracy which fuses experts drawn from different disciplines into smoothly functioning ad hoc project teams.

Little formalization of behavior, high horizontal job specialization and heavy reliance on mutual adjustment characterize this type. The complexity and sophistication of a space agency requires this configuration.

Mintzberg[1] identifies the five "pure" structural types and the list of variables characteristic of each type. This represents a good summary of the information just discussed and a reference for the next sections.

Functional Organization of a Nuclear Power Plant[4]

The nuclear power division of a utility is a somewhat autonomous division within the corporation's structure and is generally headed by a Vice President for Nuclear Operations. It is extensively supported by its own technical and administrative groups, with some interaction with other parts of the utility. For the purposes of this paper, the focus will be on an electric generation and distribution utility with a single nuclear power plant unit at one site. In addition, the plant is under operational control by the utility. It should be noted that multiple units at one site and multiple site arrangements do exist within the nuclear industry.

In general, the entire nuclear power division of a utility is physically located at the plant site. Some utilities do maintain a few groups, such as nuclear engineering, at corporate headquarters. At the site, the Plant Manager (under the V.P. for Nuclear Operations) is directly responsible for all site activities. In general, the two main goals of the nuclear division are the safe operation of the plant and the economical generation of electricity. In addition, the United States Nuclear Regulatory Commission (NRC) oversees the entire operation of each commercial nuclear power plant in the country by maintaining an on-site presence, and ensuring enforcement of many rules and regulations for safe operation.

The functional organization on site at a nuclear power plant generally contains the following units: Operations, Maintenance, Instrumentation + Control (I+C), Quality Assurance (QA), Test & Performance, Health Physics, Chemistry, Independent Safety Engineering Group (ISEG), Administration, Nuclear Licensing, Outage Planning, Reactor Engineering, Design Engineering, Shift Technical Advisors (STAs), Records Management, Spare Parts, Security, and Training. There are also two important standing committees: the Offsite Review Committee and the Plant Operations Review Committee. A typical site employs 300 to 600 people with increased numbers during major outages. The size of each specific unit varies considerably across plants. Each identified unit has been described in detail elsewhere[5].

An Organizational Model of a Nuclear Power Plant

Using the model provided by Mintzberg, the nuclear power plant (NPP) can be identified as a particular organizational structure. A fit into a "pure" type for the entire plant is not evident, but a basic structure does take shape, and the inconsistencies within the model are very manageable within Mintzberg's theory.

Utility Structure

At the utility level, the divisionalized form best represents the corporate structure. The Division of Nuclear Operations is identified as one division situated in the operating core of the utility. The Vice President for Nuclear Operations represents the middle line of the corporate structure, but will become the

strategic apex of the plant structure. The key coordinating mechanism for the utility is the standardization of outputs and the various design parameters and contingency factors associated with this structure conform closely to those described by Mintzberg for the divisionalized form.

Of greater concern in this paper, is the organizational structure of the NPP itself. Its relationship to the corporate structure will be considered when the flow of decision-making and authority within the utility directly impact on the plant. This channel of communication will occur through the Vice President of Nuclear Operations, or another individual in the strategic apex of the plant structure.

Plant Structure

The model of a NPP under consideration in this paper is initially best depicted by the machine bureaucracy structure and is presented in Figure 2. The key part of the machine bureaucracy is the technostructure, and many of the nuclear power plant units fit into that technostructure. Units such as licensing, training, quality assurance, health physics, engineering, shift technical advisors, planning and scheduling, testing and performance, and the independent safety and engineering group, comprise the technostructure of the plant's organization. These are highly developed groups which formalize and standardize the work primarily of the operating core. Much of the work and behavior in a NPP is highly formalized and procedure-based, resulting in the use of standardization of work as a key coordinating mechanism within the organization.

CONCEPTUAL MODEL OF A NUCLEAR POWER PLANT

Figure 2. Conceptual model of a nuclear power plant

Support staff in a machine bureaucracy are also organized into well developed units to reduce the ambiguity of their function and position within the organizational structure. Records management, payroll, administration, security, cafeteria and housekeeping personnel are examples of the support staff of a NPP.

The strategic apex of the NPP usually consists of the Vice President for Nuclear Operations, from the utility structure, the Plant Manager and Assistant Plant Manager. These individuals are responsible for the fine tuning of the plant, the coordination of functions, and the resolution of any conflicts occurring among the various units in the plant.

At the heart of the plant is the operating core, and it is here where the "pure" machine bureaucracy structure is not totally applicable. The operating core is comprised of three different types of units:

operations, maintenance, and instrumentation and control (I+C). In a "pure" machine bureaucracy, the entire operating core would be horizontally centralized. In an NPP, the operations unit has some vertical centralization, both functionally and structurally, over the maintenance and I+C units. Therefore, this unit conceptually resides in a different place in the proposed organizational model from the other two units. We propose that part of the operations unit comprises the middle line structure in the NPP. Specifically, the Operations Manager and Shift Supervisor are part of the middle line, while the auxiliary (non-licensed) and reactor operators remain part of the operating core. (Also, included in the middle line are the managers of other units in the NPP.) The position of the senior reactor operators is dependent upon their functional role, which is often dependent upon the operating conditions within the plant. The senior reactor operators could, under certain circumstances, reside in the middle line structure of the plant. Under normal operating conditions, they are part of the operating core.

Within the operations unit, a hybrid exists between the machine and professional bureaucracy. Most reactor operators want to be treated like the operating core of a professional bureaucracy, but the nature of their work, use of detailed procedures, and lack of complete professionalization in this unit more often resembles a machine bureaucracy. The dichotomy in types is reflected in the conflict often prevalent in this unit.

The maintenance unit within the operating core of the NPP is organized and run like a "pure" machine bureaucracy. The majority of work is routine and standardized, and authority is vertically centralized. The instrumentation and control unit, however, somewhat resembles the structural type of a professional bureaucracy. The personnel in this unit are skilled professionals with much individual autonomy over their work. Centralization in the I+C unit is both vertical and horizontal. One exception to the professional structural type within I+C is that the work being performed is often standardized, eliminating the creativity and discretion of the "true professional."

Summary

The NPP is probably best described as a machine bureaucracy with some differences in structure within the operating core. These differences, however, do not significantly effect the overall organization of the plant and how it functions. An important condition that drives this organization to a machine bureaucracy is its special need for safety[6]. Procedures are formalized extensively to ensure that they are carried out and result in safe operation. The airline industry is another example of what Mintzberg identifies as a "safety bureaucracy." Key supervisory and managerial functions are best depicted within the machine bureaucracy, and most authority within the plant is vertically centralized.

An additional point to address when dealing with any aspect of the organization of a nuclear power plant is that it is an organization whose need to structure centers around crisis. In Mintzberg's terms[7], there is a professional overlay to this day-to-day functioning machine bureaucracy. The professionalism is exemplified in the high level of training and skill required for dealing with crisis situations. Several aspects of this idea seem clear: The plant is designed for "no" failure; at the hardware level, through engineering and design, and at the software level through procedures and the technostucture in its standardization of work. The plant is operated for no failure through the training and requirements of its operating core; the speci-

fications for maintaining its hardware and the regulatory control over its operations. Finally, the plant should be able to deal with failures through its structural organization and the level of preparedness at which it operates.

The proposed organizational structure of a NPP that is described in this paper provides one means of conceptualizing the dynamics of a NPP organization. The model as described by Mintzberg is process-oriented and allows for the identification of the key supervisory and managerial influences on plant performance through the evaluation of organizational processes. Examination of the design of standards, both in hardware and software (technostucture), the application of standards through the operating core and the feedback on these standards from the operating core back to the technostucture, are critical in understanding the functional dynamics of an NPP[8]. Evaluation of the design parameters, functional characteristics, and contingency factors associated with the structural type identified will also help to uncover the pathways by which the organization functions. Behavioral factors unique to supervisory and managerial influences can then be identified for further examination.

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