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Organizational Structure and Risk Mitigation

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ABSTRACT OF THE DISSERTATION

Organizational Structure and Risk Mitigation

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This dissertation examines the link between various aspects of organizational structure and the ability of organizations to mitigate risk. A new model of risk mitigation is generated based on grounded theory and the examination of five cases of catastrophic organizational failure.

The model developed hypothesizes that five factors are important to risk mitigation. The first factor is process auditing--regular internal monitoring by members of the organization to ensure that rules are being followed and that hazardous conditions are not arising. The second factor is the nature of the reward system--which can induce individuals to act in ways that will help the organization mitigate risk or can induce them to act in ways which increase risk

for the organization. The third factor is the quality of operations relative to industry standards--organizations with high levels of quality in their operations should encounter less risk. The fourth factor is risk perception--the way in which the organization is able to perceive the risks it faces and thereby take appropriate actions. The final factor is command and control--the degree to which organizations have strong formalized sets of rules and regulations, which can serve to mitigate risk.

Previous research in the area of risk and catastrophic failure had looked almost exclusively at organizations which were high in technological complexity and no comparative analysis had been done in testing existing models. My study used organizations that were low in technological complexity and which were all in one industry. Some were failing and some were successful, so comparative research was possible.

Ten banks were used as the research sites. Two methodologies were employed--structured interviews and surveys. Analysis of the data from the qualitative study supported all five hypotheses and the theoretical model. The data from the quantitative study supported two of the hypotheses and provided weaker support for the theoretical model.

CHAPTER 1

INTRODUCTION

1.1 Theoretical Overview

In recent years the topic of risk in organizations has gained increasing attention, particularly as the incidence of catastrophic failures (such as Bhopal, Exxon Valdez and Chernobyl) has increased. While a great deal of research on risk (defined here as the potential for significant negative outcomes) has been done, there are significant limitations in the literature. This dissertation seeks to resolve some of these limitations, as well as add to existing theory about organizational structure and risk mitigation.

The existing literature is limited in part because it confines itself to various specific contexts of risk. The "disaster" literature looks exclusively at catastrophic failure in high risk environments (i.e. Shrivastava's work on Bhopal, 1987; Perrow, 1984). At the opposite end of the spectrum are researchers who look at non-failure of possibly catastrophic magnitude in "high reliability organizations" or HROs (i.e. Roberts & Rousseau, 1989; Roberts, 1992; Weick & Roberts, 1993). These are organizations which have a high potential for failure but where failure occurs much less often than would be predicted or expected (i.e on the flight deck of a naval aircraft carrier, see Roberts, 1992). However, the writers in both bodies of literature have so far, for the most part, failed to test their theories and conclusions about the causes

of failure/non-failure in an opposing context. For example, when Perrow, who writes in the "disaster" literature, makes conclusions about the inevitability of accidents, we find his conclusions undermined by the existence of organizations that "should" be having failures or accidents according to his model, but which are not. Similarly, in looking at Roberts' model of high reliability organizations, we don't know if the explanations she gives for non-failure or accident avoidance would hold up if failing organizations were tested alongside non-failing organizations in her model. (Note: In Roberts' recent book, New Challenges to Understanding Organizations she does include a chapter with an examination of the Exxon Valdez accident. However, her conclusions about the cause of the accident are much more limited than the model that will be proposed later in this paper.)

Clearly, one of the weaknesses in the theoretical development of the literature in this area is the lack of studies which have used comparative analysis. A study which looks at approaches to risk within a single industry, including organizations which are successfully coping with risk and those that are failing to handle risk well, would make a significant contribution. This study will examine a set of ten organizations, all within the same industry, some failing and some successful, and will use comparative analysis in hopes of building a more generalizable model about risk.

Another weakness in the risk literature is that with a few exceptions (Turner, 1976, 1978), it is confined to studies where the setting involves high

technological complexity. In fact, Perrow (1984) concludes that accidents in a high risk environment are "normal" and unavoidable when humans interact with highly complex technological systems. However, we can easily find examples of risk and failure arising out of more mundane organizations and situations. For example, in 1992, a Salomon Brothers clerk executed a trade incorrectly leading to a major drop in the stock market almost instanteously (See Power, Siconolfi & Sawen Wall Street Journal, March 27, 1992). Similarly, the Chicago Flood in 1992 was a major disaster caused by a break in an ancient brick wall (extremely low-tech) separating the river from underground areas in the city's downtown (see Business Week, P. 42, April 27, 1992).

Thus, there is a need for research in organizations that experience risk but which are not necessarily highly technologically complex. By eliminating high technology as a variable we can accomplish two things. First, Perrow's entire thesis that accidents are the result of the collision between humans and high technological complexity can be called into question. Furthermore, by doing so, we can develop a model which is more generalizable across a wider range of organizational settings. This study, which will look at the commercial lending process in banks, takes place in a context which is very low in technological complexity.

Another problem, particularly with the existing high reliability organization research is that the HROs examined by Roberts and her colleagues tend to be places were the risk or dangers involved are extremely obvious.

Even laymen know that flight decks of naval aircraft carriers, nuclear power plants, or air traffic control systems are highly complex, dangerous and brittle systems. HRO theory tells us relatively little about how organizations deal with risks that are not so clearly obvious in daily operations.

Finally, Roberts has made a major contribution to theory about risk in HROs, (Roberts, 1992) by identifying four major factors which she has found important to risk mitigation in the organizations she has studied. I have combined these factors together and called them "command and control" factors. What we don't know is whether or not there are additional significant factors which contribute to risk mitigation, and if so, what those factors are. This study will attempt to identify factors beyond those outlined in the current Roberts model.

1.2 Dissertation Parameters

Risk Defined: As noted parenthetically in the introduction to this paper, risk is defined as the probability of an event with significant negative outcome for the organization. However, in the literature, generally two definitions of risk exist, and it is important to explain how the above definition was chosen. The first definition, most often associated with portfolio theory, defines risk in terms of variance (Pratt 1964; Arrow, 1965, Sharpe, 1964, 1977). According to this definition, assets with high variance of returns, **BOTH** positive and negative, are considered more risky than those with low variance. However, as researchers have pointed out (MacCrimmon & Wehrung, 1986; March &

Shapira, 1987) most managers associate risk solely with uncertainty about negative outcomes. In addition, the literature cited so far in this paper (from both the disaster and HRO perspectives) considers risk to be associated with high consequence negative outcomes.

In dealing with highly complex technology, the consequences are often measured in human terms as well as monetary terms. In this paper, since we will be dealing with low technology which does not involve a threat to human life, high consequences will be measured in dollar terms and/or the potential that the outcome might cause the failure of the firm.

Dimensions of Risk: Risk theorists often look at risk in a general or abstract sense, drawing conclusions that are generally based on the results of laboratory studies, (e.g. Douglas & Wildavsky, 1982; Kahneman & Tversky, 1979; Sitkin & Pablo, 1992). In doing so, they fail to acknowledge that risk has numerous dimensions which may affect the way in which an organization (or individuals within it) behave with respect to risk. At least three such dimensions can be identified which are useful for dealing with risk and organizations: locus--internal vs. external; level--strategic vs. operational; and magnitude--small vs. large.

Risk to firms or organizations can arise from external threats (such as corporate terrorism as in the Tylenol case, disasters such as the Los Angeles riots or Oakland fire, or from hostile takeovers). Risk can also arise from internal processes (defective products like the Shiley heart valves, poor safety

practices as in the Bhopal case or from faulty internal monitoring systems as in the case of the Chicago Flood).

Risk can also arise out of one-time strategic decisions (such as deciding to pursue an acquisition or leveraged buy-out, to put a new product on the market, or to change marketing strategies). Or, risk can arise out of day-to-day operational activities (like going to sea, as in the case of the Exxon Valdez).

Finally, risk can vary in terms of magnitude. The most common way of measuring magnitude is in terms of the potential financial impact that a given risk poses for the organization. Several researchers note that risk of large magnitude may affect decision making by individuals differently than do risks of small magnitude (Kahneman & Tversky, 1982; MacCrimmon & Wehrung, 1986; March & Shapira, 1987).

With respect to the above three dimensions, much of the risk literature has focused on strategic rather than operational risk (Baird & Thomas, 1985; Bowman 1980; Sitkin & Pablo 1992). Considerable research has also been directed towards risk that arises from external causes (e.g. Mitroff & Kilmann, 1984; Pauchant & Mitroff, 1992), as opposed to internal causes. And, as will be noted further in this paper, risk research in the area of magnitude is limited by its dependence largely on lab studies in which the magnitude of the outcome is far from catastrophic and often of little real significance.

Therefore, an additional contribution that this paper will make will be the exploration of risk in dimensions that have been been the focus of limited

research to date. In this paper, the focus will be on risk that is operational in nature, internal in terms of source, and of large magnitude.

Unit of Analysis:

Much of the research on risk has focused on individuals or decision makers as the unit of analysis (e.g. Kahneman & Tversky, 1979, 1984; March & Shapira, 1987; Sitkin & Pablo, 1992). Other researchers have focused on groups, notably the "groupthink" phenomenon which can lead to dysfunctional approaches to risk (Janis 1972; Janis & Mann, 1977). However, this study will focus on the organization as the unit of analysis.

The organization will be the unit of analysis for two reasons. First, much of the anecdotal literature on organizational accidents or catastrophes implicates the "organization" itself, at least implicitly, when placing blame for the negative outcome. However, systematic study of the organizational features of risk-proneness or risk-mitigation have been limited to date. Second, individuals can be conceived as organizational actors in this framework. The existing research on behavior with respect to risk then becomes important only as it is related to the organization and its structure.

For example, the response of organizational actors to the reward or punishment system within an organization can be predicted using various individual risk behavior theories (particularly Tversky & Kahneman, 1979 and March & Shapira, 1987). However, it is the organization that sets up the reward and/or punishment system.

1.3 Sequence of Following Chapters

The next chapters will be laid out in the following manner. Chapter two will examine the existing literature on risk and point out some of the problems in applying that literature outside of the laboratory in organizational settings. Furthermore, chapter two will thoroughly outline the research conducted in the "disaster" literature, the HRO literature, and the limited literature (Turner, 1976, 1978) on disasters in low technologically complex settings (although Turner does not define them as such). Chapter two will not be used to build the model and hypotheses, as would be the typical case, because the research in this area is so limited to date. Instead the literature reviewed in chapter two will be used in chapter three to help build the model in the method described below.

Chapter three will build the model and generate a set of hypotheses to be tested using grounded theory methodology. Five case studies of prominent and well documented organizational failures will be examined in order to find common causes or factors which seem to have contributed to failure. The cases to be used are the Chernobyl nuclear plant explosion, the Space Shuttle Challenger disaster, the Bhopal chemical plant spill, the Exxon Valdez tanker spill and the improper grinding of the Hubble Telescope mirror. The literature and theories from chapter two will be incorporated into the model, and differences between the model and some of the conclusions reached by others will be noted. In general, the theoretical work of Roberts and Turner will help support the theoretical model that I will derive from the cases.

Chapter four will focus on the methodology used in testing the model developed in chapter three. Ten banks were used in the study and two methods of data collection were used. Interviews were conducted in all of the banks, and questionnaire data was also collected from all of the line lending officers at the ten banks in the study.

Chapter five will review the results from the interview data, and will analyze the results to see how well they fit the model and hypotheses laid out in chapter three. I will try to find common causes or factors which seemed to contribute to each bank's success or lead to portfolio problems with respect to its commercial loans. Chapter five will use data derived from interviews collected at each of the ten banks. The factors derived from analysis of the interview data will then be compared against the model proposed in chapter three, and similarities and dissimilarities between the models will be discussed.

Chapter six will test the quantitative data derived from surveys of line lending personnel conducted at all of the ten banks. Factor analysis of the questionnaires will be conducted to identify common factors in portfolio risk management. Regression analysis will be used to regress the factors against performance results for each bank. The results from chapter six will be compared with those from chapter five (the qualitative data) and with the model set out in chapter three.

Chapter seven will provide a summary, a conclusion, and further research agenda. In this final chapter, I will show how the dissertation achieved the objectives as intitally set out in chapter one.

CHAPTER 2

LITERATURE REVIEW

2.1 Definition of Terms

Organizational Failure: The phenomenon under study in this research is negative outcomes of large magnitude. I have chosen the term organizational failure to describe such incidents. The term refers to events (or a series of events) that culminate in a significant (in financial terms) threat to the organization, even though such an event may not cause the death of the organization. For example, for a bank, organizational failure could result from poor lending practices (the "event") leading ultimately to a declaration of insolvency by the FDIC (significant financial magnitude). Degrees of failure are also possible in this situation, since the FDIC and other federal regulators can impose less severe but nevertheless highly restrictive sanctions on the banks such as a "cease and desist" order (restricting lending activity) or a "memo of understanding" (requiring the bank to do certain things such as increase its capital ratio, improve its internal auditing etc.). For other organizations, such as a manufacturing firm, the production of a defective product might lead to massive product liability claims threatening the organization's solvency (i.e. Shiley's heart valves, Johns-Manville asbestos products and the Dalkon shield). In the recent case of Salomon brothers, a few illegal trades in government securities cost it hundreds of millions of dollars in settlement with the U.S.

government and severely tarnished its reputation.

Risk Mitigating Organizations: These are organizations which engage in activities that reduce the probability that organizational failures will occur, despite the fact that these organizations operate in a high risk context. All other organizations will be considered non-risk mitigating and I will not differentiate betweeen those which are merely passive about risk and those that engage in risk-seeking behavior. The comparitive analysis will be comparing risk mitigating organizations to those that are non-risk mitigating.

Probability and Risk: For several centuries, mathematical theorists have been trying to model human behavior towards probability and risk. In general, these models are based on a notion of economic or rational man who maximizes expected utility along some given utility function. Such an individual would prefer a 10% chance of winning $1000 (with an expected value of .10 x $1000 = 100) to a 2% chance to win $3000 (with an expected valued of .02 x $3000 = 60). Unfortunately, in the lab we find that a lot of individuals would choose the 2% chance to win $3000 despite its lower expected value. One way that economists and theoreticians have dealt with this problem is by constructing elaborate ultility functions which "explain" such behavior.

Expected utility theory has been the leading theory in explaining the behavior of decision makers under uncertainty from the 18th century on, despite a number of problems or paradoxes which continually crop up in the effort to match models with human behavior. The first paradox was proposed by

Bernoulli in 1713, and others have followed. Mathematical rigor was added to the field in 1947 by von Nueman and Morgenstern who proposed a set of axioms or rules that must be obeyed by "rational" decision makers. Theory was subsequently built on these and other axioms discovered by others including axioms such as independence, transitivity and the reduction axiom. However, as quickly as mathematical models were formulated, paradoxes soon appeared (Allais' paradox, Allais, 1979; Ellsberg paradox, Ellsberg, 1961). The paradoxes showed that under certain situations, humans would behave in a way that was inconsistent with theory and that they would violate one or more of the axioms underlying such theory.

Although theorists are continuing to search for a mathematical model to describe choice under uncertainty that will be free from paradoxes, a psychological approach has been devised by Tversky and Kahneman based on empirical observations of human behavior. Prospect theory (Tversky & Kahneman, 1973) represents a modification of expected utility theory and can accomodate observations of "irrational" choice behavior. Because of its applicability to "real world" decision making in which many choices seem to be irrational in retrospect (especially risky choices), I will use the Tversky and Kahneman framework in analyzing decision problems in this dissertation.

2.2 Prospect Theory

Prospect theory provides a rich model of human behavior under uncertainty (Kahneman & Tversky, 1979). However, there are several parts of

the model that have particular relevance in this paper. Specifically, Kahneman and Tversky stipulate that:

1. Losses loom larger than gains.

2. Low probabilities are overweighted.

3. Overweighting of certainty relative to uncertainty leads to:

    a. risk-averse preferences for a sure gain over a probable larger gain.

    b. risk-seeking preference for a possible loss over a sure gain.

The meaning of the first two propositions is that they provide good explanations for seemingly opposite observable behaviors such as purchasing insurance and gambling. A person purchases any type of insurance because the potential loss "looms large". Even though the expected value of the loss is less than the premium (that is how insurance companies make money), if the loss occured, it would overwhelm the insured so the insurance is purchased to hedge against such an event.

In the case of gambling, the overweighting of small probabilities explains why people engage in even the most extreme gambles such as lotteries (they overweight the probability of winning).

Risk-seeking behavior is also an important concept in the risk framework being laid out in this paper. Later in the paper I will explain in more detail how organizational structure encourages or discourages risk-seeking behavior. For now, a case from Perrow (1984) illustrates why the concept is so important.

Perrow describes the choices of a captain who was piloting a large oil tanker, the Torrey Canyon. The captain was in a hurry to get to a port in Wales; if he did not arrive in time, the fluctuating tides would force him to wait outside the port for five days (costly for the company and no doubt involving some penalty to the captain). The captain was faced with the choice of going the safe way and missing the tide, or with taking a shortcut through the treacherous waters of the Scilly Islands to save six hours (the Scilly Islands have been notorious for centuries as a graveyard for ships). The captain chose the shortcut, ran aground, and ended up spilling 100,000 tons of oil in the English Channel.

The captain's behavior fits the Kahneman and Tversky model perfectly. If he had gone the safe way he faced a sure loss in terms of some type of penalty or censure from the company. In choosing the shortcut, he faced the possibility of a large loss, but also the possibility of avoiding loss altogether. As the model predicts, he attempted to avoid loss, despite knowing that his choice involved the potential for very large loss.

One more point about this case is that it illustrates the importance of focusing on the organization as the unit of analysis. Although the captain was the decision maker in this situation, it was the rules and penalties of the organization that influenced his behavior.

2.3 Technology As A Source Of Risk

The theory that high technology itself is the main source of catastrophic

risk has been put forth by Perrow (1984) in his book Normal Accidents. Perrow makes the argument in reviewing a large number of catastrophic accidents that the reasons for failure were the system characteristics of interactive complexity and tight coupling. Furthermore, the complexity is such that interactions occur in the systems that are not only unexpected but "incomprehensible for some period of time" (p. 9). At the end of his book, Perrow argues that limits on technology are necessary in order for us to avoid inevitable and even "normal" catastrophic accidents.

While one cannot dispute that interactive complexity and tight coupling of processes make systems more risky, Perrow's thesis can be challenged mostly because he fails to look beyond those causes. For example, in his book, he cites the case of the Flixborough disaster in England in 1974. Flixborough was a chemical plant that used a process involving six reactors to produce finished products. In the course of operations, the Number 5 reactor was found to be leaking and subsequently a six foot long crack was discovered. As a result, the plant managers decided to bypass the Number 5 reactor (thus connecting Reactor Number 4 directly to Number 6) and keep the plant running. As Perrow cites from the official report later published:

> "...no one appears to have appreciated that the connection of No. 4 Reactor to No. 6 Reactor involved any major technical problems or was anything other than a routine plumbing job...in fact no drawing was ever made, other than one in chalk on the workshop floor; no calculations of strain were made; the designer's guide for the large bellows the by-pass pipe would be connected to was not consulted and so on. The bypass was completed after two days...The scaffolding that would hold the 20-

> inch pipe was rudely constructed in the rush to get the plant back on-line. The supports were wholly inadequate and some were omitted, presumably in haste." (p. 109).

About one month after the bypass had been installed, the plant exploded, killing twenty-eight employees and injuring thirty-six other employees. Fifty-three people in the surrounding area were also injured, and a great deal of damage was done to local houses, shops and factories.

This example, given by Perrow, undermines his very thesis and raises some other interesting questions. We see that, at the time the decision to bypass the reactor was made, no tight coupling was involved. The plant supervisor and others were not operating within the tightly coupled decision parameters that apply to individuals such as air traffic controllers. The tight coupling of the system occured only after Reactor No. 4 was hooked to Reactor No. 6. Furthermore, it is not at all clear from the account that the interaction between the reactors was necessarily baffling or "incomprehensible for some period of time", to individuals who were competent. From Perrow's account it appears that a logical explantion for the accident is sheer incompetence and negligence (he admits that this played a part but insists that the complexity of the system was the main underlying cause of the catastrophe).

At least one question that this example raises is one that will be raised in looking at other catastrophes later in this paper. Specifically, what other factors besides technological complexity were operating in contributing to this disaster? i.e. Why didn't the plant manager have proper engineering drawings made up?

Why was there so much pressure to get the plant up and running? Why wasn't more attention paid to the hazards and risks associated with running a plant producing dangerous and highly flammable chemicals?

While Perrow's work certainly cannot be entirely dismissed, we see that it has limitations because of its narrow focus on technology as the major source of catastrophic risk.

2.4 Catastrophes in Low Technological Settings

That catastrophes happen in low technological settings is a fact that can be confirmed by simply reading the daily newspapers and magazines. Events like the Chicago flood, the recent Amtrack rail disaster (involving a lost river barge and a railway bridge) and the Salomon Brothers trading error happened in environments that were low in technological complexity.

Much of what we know about catastrophes in such settings is anecdoctal in nature. The literature tends to be of a fact-finding journalistic style. However, one author, Turner (1976, 1978) examines three low-tech catastrophes in England with the intention of coming up with some similarities among them in terms of pre-disaster phenomenon. (Note: Turner is interested in the similarities between the disasters and does not note that they take place in settings characterized by low technology; that is my observation).

Turner looks at the following three disasters:

1. ABERFAN -- " ...a portion of a colliery tip on a mountainside at Aberfan slid down into the village in 1966, engulfing the village school, and killing 144 people including 116 children". (p. 53)

(Note: a tip is a pile of rocks and rubbish that accumulates near coal mines as a result of the mining activity.)

2. HIXON -- "...at Hixon in Staffordshire... a large road transporter 148 feet long carrying a very heavy transformer was hit by an express train while it was negotiating a...railway crossing, killing three railwaymen and eight passengers on the train. The transporter moved at 3 feet/second and therefore could not clear the crossing in the 24-second warning period." (p. 53)

3. SUMMERLAND -- "a holiday leisure complex at Douglas, Isle of Man, with approximately 3000 people inside caught fire... The building, an open structure clad partly in sheet steel and partly in acrylic sheeting, burned rapidly and 50 men, women and children in the building died." (p.53)

In looking at these three organizational failures, Turner identifies seven factors that contributed to the disasters. Those factors will be be summarized here. As noted earlier, I will refer back to these factors in chapter three as I develop my model of risk mitigating behavior and the related hypotheses to be tested. Later in this paper, I will also examine the similarities and differences between my findings and those of Turner.

The first factor that Turner identifies is "Rigidities in perception and beliefs in organizational settings" (p. 58). He points out that cultural and institutional factors inhibit the accurate perception of the possibility of disaster. Turner notes that in the case of the Aberfan coal disaster "the pervasive set of beliefs and perceptions within the coal industry was...oriented almost wholly towards the problems, difficulties and activities of underground mining, and away from tips as being in any sense important for those involved with mining" (p. 58).

exacerbated the emergency--the planners of the safety systems and emergency exits did not forsee such behavior.

The sixth factor is relatively self-evident, "Failure to comply with regulations already in existence" (p. 70). Regulations are obviously designed to mitigate risk. When organizations fail to comply with the regulations, risk is necessarily heightened.

Turner's seventh factor is "Minimizing emergent danger" (p. 71). He notes that in early states, some idea of the danger of the situation is recognized, but that it is seriously underestimated. He also notes that a syndrome of denial persists often into the disaster itself. "At Summerland the staff failed to call the fire brigade promptly and the elaborate fire-alarm system was not used at all, one of the first warnings of the fire being given by a ship at sea which spotted the blaze on shore." (p. 74)

2.5 High Reliability Organizations

Roberts and others (Roberts & Rosseau, 1989; Roberts, 1992; Weick & Roberts, 1993) have identified a set of organizations that they characterize as "high reliability organizations" or HROs. These are organizations which have a tremendous potential for catastrophic failure, but in which the incidence of accident or failure is much lower than it "should" be. Most written about by the HRO reseachers are the flight decks of naval aircraft carriers, which are highly dangerous and complex organizations where the accident or failure rate has declined steadily over time.

Roberts and her colleagues spent time looking at HROs to find out why they didn't have the type of "normal" accidents that Perrow predicts despite the presence of features such as tight coupling, sometimes baffling interactions and high complexity. Roberts (1992) identified four key factors that contributed to risk mitigation in HROs. They were:

1. Command by exception or negation
2. Redundancy
3. Procedures
4. The ability of management to "see the big picture".

Command by exception or negation refers to management activity in which authority is pushed to the lower levels of the organization by managers who constantly monitor the behavior of their subordinates. Thus the managers provide checks and balances on the activities of those below them, and the managers can readily step in when problems arise (this is known as decision migration). In these organizations, the decision making responsilibility is allowed to "migrate" to the person(s) with the most expertise to make the decision when unfamiliar situations arise. This migration is often upward, but it can also be downward or lateral.

Redundancy in HROs is accomplished with respect to both people and hardware. Roberts, Stout & Halpern (in press), point out that the air traffic control tower on the flight deck of an aircraft carrier has multiple redundant communication systems (hardware redundancy). Similarly, the process of landing a plane on the flight deck involves numerous individuals who serve as

redundant decision makers because any one of them can abort the landing if they spot a problem (people redundancy).

Procedures and rules are also an important part of the reliable functioning of the organizations Roberts studies. These procedures and rules are codified in thick manuals and cover nearly every aspect of operations. Adherence to the rules is emphasized in these organizations as a way to prevent errors.

Finally, Roberts finds that the organizational structure of these organizations allows key decision makers to understand the "big picture". "People with the big picture can capture various migrating decisions and integrate them" (Roberts, 1992, p. 23). Thus, the job of a senior officer on an aircraft carrier consists of integrating information from various sources about a particular problem and then making an effective decision.

2.6 Chapter Summary

In this chapter I reviewed the literature that is relevant to this dissertation. The Tversky and Kahneman framework was summarized and I showed how their framework for individual decision making under conditions of uncertainty (risk) is a useful one for my purposes here.

Second, I reviewed and summarized the theoretical perspective of Perrow who believes that highly technologically complex systems are doomed to "normal" accidents with ultimately grave consequences for mankind. I provided a critique to his arguments and noted that his thesis is also criticized by the

HRO researchers.

Third, I reviewed the only literature of an academic and theoretical nature that seems to be available on catastrophes that have taken place in a setting that is characterized by low technological complexity (Turner, 1976, 1978). Other authors have not followed up on Turner's work (he is not mentioned by Perrow or the HRO researchers), so his conclusions about the similarities between the three catastrophes he reviews remain untested and apparently have not been critiqued. Furthermore, Turner's findings cut across industries and focus only on failures--thus his work is less than the scope of the contribution that I hope to make in this paper. However, I will use some of his theories to support the model I will be building in chapter three.

Fourth, I reviewed and summarized the high reliability organization (HRO) literature. In building the model in chapter three, I will draw from Roberts' ideas about the command and control system and I will include the four elements of the system that she has found to be important in risk mitigation.