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INTRODUCTION

Crisis management includes assessment of risks, determination of the way to achieve the lowest possible (or acceptable) level of risk, the establishment of systems and procedures to maintain the system at an acceptable level, the preparation (contingency planning) required to deal with events which could take place, and the management of response organizations and actions resulting from this preparation when an incident occurs. Each of these elements has an economic cost and a key element in crisis management is the rational allocation of these costs. The objective of this paper is to examine the integration of prevention, planning and response in the management of maritime crises. The paper concludes with a preliminary analysis of the EXXON VALDEZ incident based upon a National Science Foundation funded rapid assessment study conducted by the authors.

Maritime crises, involving the saving of lives and the salvage of ships and cargo, have been a result of maritime commerce since man first started moving goods by water. Rescue and salvage organizations evolved throughout the world and have historically dealt with maritime casualties in a professional (and often heroic) manner. The costs of maritime casualties historically has been absorbed by a complex system of underwriters and Prudential and Indemnity clubs. A turning point in maritime history occurred on March 18, 1967 when the 117,000 dwt super tanker TORREY CANYON stranded on the Seven Stones rocks in the area of sea between Cornwall and the Isles of Scilly. A minor human error caused the incident--the automatic control switch was locked on, disengaging the helm. (Ironically, a similar action is believed to have contributed to the EXXON VALDEZ incident.) The inability of existing maritime response organizations to deal with the 100,000 tons of escaped crude oil was soon evident. The maritime crisis event was redefined: society realized that it must somehow learn to protect itself and the environment from the cargo released during a maritime casualty.

Progress in dealing with this new type of crisis has been slow. The grounding of the tank vessel ARGO MERCHANT off of Cape Cod in December of 1976 provided evidence that the problems of oil spill prevention and response had not been solved. In a 1979 article reviewing the progress of oil spill cleanup in the ten years since the Torrey Canyon incident, White, Nichols and Garnett state that "little progress has been made over the past decade to reduce the impact of oil spills to the extent that available technology should allow". In a 1979 report the National Research Council of the National Academy of Sciences stated that, "little attention has been paid to how government and industry would respond to a major maritime casualty involving hazardous cargo...[and]..the technical community...is concerned about the capability to do so." In a 1984 Management Science article, the authors stated that, "the problem of providing an immediate response [to an oil spill] in areas where major environmental damage may be done in less than 6-12 hours has not been solved or extensively studied. The environmental damage caused by oil spills in these areas could be massive and the public interest would be intense. In these areas, the national strategy fails."

The difficulty in preparing for and responding to oil spills stems from the fact that these are extremely rare events with impacts far greater than those experienced during more routine emergencies. Society does not deal easily with low probability high consequence events, particularly when the risk is due to a technological hazard. Wenk (1986) notes that the catastrophic event is qualitatively different from less severe accidents; an observation that is particularly true when applied to oil spills. Karwan (1985) points out, for example, that, "a large spill response strategy involves preparing for spills over 625,000 times larger than the median spill or over 4,400 times the average spill." Psaraftis (1985), states that "strategic oil spill response decisions typically involve planning horizons of considerable duration (e.g. 5-15 years).

The public's attitude toward low probability, high consequence events tends toward polar extremes. Most people rarely think of the event and when they do they focus on the low probability and assure themselves that the high consequence event will never happen and that untested response plans will be adequate if it does. Others see only the consequence of a catastrophic event and insist the activity should not be allowed no matter how small the risk.(e.g. the reaction of many people to the nuclear power industry after the Three Mile Island incident). This position gains adherents immediately after a major incident when public interest in the risk and consequences of a catastrophic event is intensely shown for a brief period. If, however, the event does not reoccur, interest diminishes rapidly over time. The public response to the risk of a major oil spill follows this pattern, identified by Wenk (1986) as, " the politics of risk": neglect until some event dramatizes an old and hidden but significant danger and then over-reaction. We deal routinely with the accidents of limited consequence, but cannot deal rationally with the catastrophic event.

In the absence of any major maritime disasters in U.S. waters during the last decade, concerns about the prevention and control of hazardous cargo releases did not become major issues. The March 1989 grounding of the EXXON VALDEZ and the resulting 240,000 barrel cargo release has shown that the environmental and societal risks associated with the maritime transport of large quantities of hazardous cargo cannot be ignored. Unfortunately, the spill also illustrated that processes which can reduce these risks are only loosely coupled, and that the relationships between these activities are poorly understood. Public acceptance of oil transport and exploration in environmentally sensitive regions has been shaken. The government and the industry are being challenged to demonstrate an ability to prevent, to plan for, and to manage a major response effort. Significant legislative and regulatory decisions will be made on the basis of this difficult demonstration.

The authors contend that an integrated examination of the areas of risk reduction, contingency planning, and incident response should be undertaken. Valuable linkages between the activities can be developed and policy trade-offs can be identified. We define these broad areas as follows:

Risk Reduction includes a wide range of actions which reduce the risk of a release of a maritime hazardous cargo. Activities which reduce the risk of ship casualties include the siting of port facilities, the configuration and marking of harbor channels, the control of vessel traffic and the establishment and enforcement of personnel standards. The risk of a cargo release resulting from a ship casualty can be reduced through cargo loading, handling, storage and ship design and construction standards.

Contingency Planning includes those actions which insure that an adequate response can be mounted to a maritime casualty involving a hazardous cargo. Contingency planning includes the development of accident scenarios, the gaming of the possible consequences of these scenarios, and the identification and creation of the organizational, financial, and physical resources required to minimize the impact of these incidents.

Incident Response includes a series of related actions intended to minimize the impact of an incident once it occurs. They include the countermeasure actions taken to salvage the ship and cargo. (The National Academy terms marine salvage as "the middle ground between preventing casualties and cleaning up after them"). Response activities may include the evacuation of populations (if the threat of toxic exposure or fire exists) and will include all actions taken to "clean up" after the spill. As the EXXON VALDEZ incident shows, these actions are constrained by the resources and organizations created through the contingency planning process.

THE ANALYSIS OF CRISIS DECISION MAKING

Once a catastrophic event occurs, responsible disaster managers must create an organization appropriate to the demands of the crisis. In order to do this, the disaster and the decisions that will have to be made in its wake must be anticipated. Contingency planning, in other words, must be scenario based and decision oriented. The generation of realistic scenarios is critical and non-trivial. Alyeska based their contingency plan on two scenarios, a routine spill and a worst case spill. The worst case scenario envisioned a 200,000 bbl release from a tanker in a 10 hour period under ideal weather conditions. The EXXON VALDEZ lost 240,000 bbls in approximately 2-3 hours. Scenario generation is a creative, challenging task requiring adequate time and expert participants. War planners have invested extensive resources generating scenarios on which to base national strategy and tactics. The National Academy of Sciences (1979) produced a study of the nation's capability of responding to a maritime hazardous materials incident based upon a set of skillfully created scenarios. Nunamaker, Weber and Chen (1989) have used the University of Arizona decision support room to facilitate the development of crisis scenarios by senior executives of major industries. Contingency planners must have clear understanding of the type of events which may occur and the relative probability of these events. A description of an event is not, in itself, a scenario. The scenario includes a description of environmental conditions, response options, tactical problems, and critical concerns.

Once a set of scenarios is generated, the decision process which will create and implement the response capability must be analyzed. This decision process is, in its simplest terms, one of pattern matching. The disaster has dimensions of location, duration, intensity, and impact. The response will have the dimensions of people, skills, equipment, money, and time. Fraser (1979), for example, discusses how realistic scenarios are critical for the selection and sizing of response equipment. Garry (1981) shows how scenarios can be used to estimate resource requirements for a state response plan. Bellantoni et al. (1979) used a set of scenarios to determine recommended deployment requirements for U.S. Coast Guard pollution response equipment. Matching the resources to the problem will require a series of decisions which must be anticipated and analyzed during the contingency planning process. What decisions must be made? What information should be available to the decision maker when these decisions are made? What are the relationships between variables and outcomes? How are the decisions constrained by available resources?

The output of this decision analysis is an identification of information requirements, identification of resource requirements and constraints, and the development of training scenarios for decision makers. The decision analysis will also predict the results of optimal response efforts and has, therefore, implications for prevention strategies. If, for example, oil spill containment and vessel salvage operations would be impossible under certain weather conditions, more stringent vessel movement control may be justified.

THE EXXON VALDEZ: A CASE STUDY

The authors were sponsored by the National Science Foundation to visit the site of the EXXON VALDEZ spill and to identify potential areas for future research. The research team found that decision making in the early hours of the response effort was constrained by inadequate planning in several ways. The most obvious symptom of inadequate planning was the lack of immediately available response resources, a fact well documented in subsequent government and press reports. More subtle, but perhaps equally serious, was the failure to anticipate the decisions and actions which a major incident would require and to develop information and decision aids which would support these actions. Such computer based aids are described by Belardo et al. (1984), Everson (1986), Harrald and Conway (1981), Mick and Wallace (1986), and Wallace and De Balough (1985). Eventually, the federal OSC, the state OSC, and EXXON all evolved computer systems to track resource allocations, clean up progress, availability of key personnel, and spill movement. These systems are relatively sophisticated, involving large data bases and geographical information systems, and literally hundreds of personal computers are in use at the spill site. Unfortunately, none of this technology was in place at the time of the spill; the information on resource requirements and availability, spill movement, and vulnerability of areas in the path of the spill were not readily available to decision makers.

In order to identify problem areas in the decision making process during the spill response, we constructed a preliminary normative model of this process during the EXXON VALDEZ incident. A normative model is a description of what should have happened, assuming that a decision maker had access to all relevant information and possessed the ability to sort and to correctly process this information.

The emergent stage of the response to the EXXON VALDEZ oil spill was modeled with the decision analysis technique of influence diagrams using the software package DAVID. The result is shown in figure 1. An influence diagram's Bayesian logic is equivalent to that of a decision tree, but it presents a much clearer visual picture of the decision process. As defined by Shachter (1987), an influence diagram is a network representation of probabilistic and deterministic variables, decisions and an objective. The stochastic variables are represented by single ovals, deterministic variables by double ovals, and decisions by rectangles. Arrows represent the direction of influence. An influence diagram not only shows relationships between variables and decisions, it implies the information requirements for decision making. Howard and Matheson (1984), Owen (1984), and Shachter (1984) show how the influence diagram can be used to model complex decision processes. Shachter (1987) shows that if a diagram's structure is determined and the outcomes and distributions of key variables are specified, then the diagram may be solved in a manner similar to a decision tree.

The process of drawing, manipulating, and analyzing influence diagrams has been made easier by the software package DAVID designed by Shachter (1988) for the APPLE

MacIntosh, SE and APPLE II computers. This package enables the creation and rapid modification of influence diagrams thus providing a useful means of communicating the complexity and inter-relationships of a decision sequence. For example, this interactive capability was used by one of the authors to assist senior disaster service managers in the American National Red Cross to analyze their crisis decision making process as a first stage in the design and development of decision aids (Harrald, 1988).

A useful interpretation of the normative influence diagram of the EXXON VALDEZ response can be made using Simon's model of the decision making process. In his information processing view of cognition, the decision making process starts with an **intelligence** gathering phase which leads to the development of alternatives, or **design** phase. Once alternatives are generated, the decision maker is able to compare alternatives and make a **choice.** The final stage is **implementation.**

In figure 1, the upper level of the influence diagram represents the stochastic and deterministic variables which must be known in order for the decision maker to make informed strategic choices. This corresponds to the diagnosis, or intelligence gathering, stage of decision making. In the EXXON VALDEZ incident, for example, the alternate Captain of the Port was sent out to physically board the vessel to ascertain the extent of the damage, the stability of the vessel, and the rate of cargo loss.

The next level of the diagram represents a series of strategic choices, the validity of which depended heavily on the quality of information available. These decisions include the decisions to offload the vessel, to initiate salvage measures, to activate the Regional Response Team, to initiate the staging of response resources, the activation of the pre-designated On Scene Coordinator organization, and the acceptance of responsibility for clean up by EXXON.

The outputs of these decisions were the organizational structures and resources (equipment and people) which were available to combat the spill in the early days. These deterministic variables acted as constraints for the round of tactical decisions which made up the next round of decision making: the use of dispersants, the allocation of containment and removal equipment, and the use of biological and burning agents to combat the oil. The variables describing the results of these decisions represent the amount of oil removed, dispersed, burned or biodegraded. Since this was a relatively small amount, the final round of decision making in the initial stage of the spill response was the allocation of booms to protect vulnerable resources, and the replacement and augmentation of on-scene resources.

The output variable describing the completion of the emergent stage of the spill response are variables describing the miles of beach affected, the impact on fisheries and bird and marine mammal populations. The influence diagram does not show the evolution of the spill response into a massive beach cleaning operation and media event. The diagram also does not show the goal of the decision process during the EXXON VALDEZ incident (which would be indicated by a rounded rectangle). It is not clear from the initial analysis that decision makers had a consistent and clear set of goals.

The diagram may be used as a basis for analyzing the information gathering, processing and alternative generation which occurred during the EXXON VALDEZ incident. More importantly, the technique shown may assist in the development of future worst case scenarios, decision aids, and information resources. Similar analyses could be conducted for hazardous cargo scenarios where a decision maker must make a series of countermeasure, evacuation and mitigation decisions based upon sparse information.

ISSUES IDENTIFIED IN THE EXXON VALDEZ INCIDENT

During the assessment of the EXXON VALDEZ oil spill, the authors: interviewed federal, state, local, and industry officials; visited command posts and clean up sites; and were provided access to records, message traffic and situation reports The following is a brief summary of issues in the prevention and management of maritime crises which were identified in the authors' analysis.

1. Externalities/Role of the U.S. Government/State Government

Ocean carriers, such as tanker owners, operate in a business environment where many externalities exist that are outside of their control. Nevertheless, these externalities may have a significant impact on their operations. Governmental bodies such as the U.S. Coast Guard, and classification societies set standards for ship design and periodic inspection. The Congress has passed laws and the U.S. Coast Guard has promulgated regulations related to the manning standards and work rules on U.S. flag vessels. The USCG also licenses seagoing personnel on U.S. Flag ships.

Liability limits on ships and oil spills have been set by external bodies. Vessel Traffic Systems run the USCG affect the manner in which ships enter a limited number of ports, including Valdez. The state of Alaska had a substantial role in minimizing the risk of a major oil spill. They permitted and inspected the Alyeska facility, reviewed and approved contingency plans, and licensed state pilots. (Jurisdiction over pilotage operations is distributed between federal and state organizations.)

It is fair to ask whether all these externalities are properly coordinated into a comprehensive package to insure vessel safety. Foreign governments do not handle all the ship safety functions in the same was as the U.S. Government does. For example, the Dutch government in the Rotterdam VTS system actively controls vessel movement in contrast to the passive U.S. systems. A comparison can also be drawn with the airline industry, where air traffic control systems and manning standards are handled somewhat differently. This may be an appropriate time to take a focused, integrated view of the maritime legal and economic environment.

2. Vessel Safety

Elements of Safety include: ship design and construction; crew training, licensing and manning standards; licensing of pilots; and the use of safety devices both on the ship and on the shore. Many safety aspects can be categorized as active or passive and internal or external. They can be further classified (see Baisuck et al. 1977) as to intent: are they designed to prevent the casualty from occurring, to prevent a cargo release after a casualty occurs, or to minimize the impact of that cargo release? To increase ship safety, one can make changes in one or more areas. Ship designs of double bottoms or double hulls must be considered. Better training of crews and drug testing are possibilities. Passive internal equipment includes fathometers, radar, etc. An active internal device would be an electronic chart or collision avoidance system with an alarm or a means of taking corrective action. External factors include Vessel Traffic Systems which are relatively passive at present when compared to the more active air traffic control system. A comprehensive safety analysis that ties together these many factors in a coordinated and efficient manner is needed.

3. Contingency Planning

The state of Alaska and the federal government accepte oil drilling, pipeline construction, and oil transportation The state has received economic benefits. The Alaskan fields significantly reduce our dependence on foreign oil and society has consciously, or unconsciously, accepted the environmental and other risks involved. Apparently, no one in authority in looking at the regional contingency plan or Alyeska plan, seriously considered that a 240,000 bbl spill could or would take place. The regional contingency plan wa inadequate for a 200,000 to 240,00 bbl spill, mainly because of the limits of technology used (which were not fully revealed in the plans because the response scenarios were not fully developed). A 1977 EXXON USA article stated for example, that "while exercising every precaution to prevent an oil spill [in Prince William Sound] Alyeska has detailed plans to clean up a spill should one occur". The state accepted Alyeska's plan. Based on existing technology and experience in past oil spills, it is unreasonable to assume that in a major oil spill, more than 20-30% of the oil will be picked up mechanically, treated with dispersants, or burned. The majority of the oil will hit the beach, a fact that was not recognized in contingency plans. The labor intensive nature of the beach cleaning operation was unanticipated.

The federal, state and corporate organizations which evolved after the spill did not conform to any organizational structures anticipated in the contingency planning process. This hampered the spill response and inter-organizational cooperation. None of the plans anticipated that the affected oil company, not Alyeska, would actually run the pollution response during a major incident. The federal on-scene coordinator and the state organization did not evolve into stable, smoothly functioning organizations until after the opportunity to deal with the free oil had elapsed. Most of the resources brought to the scene by EXXON and by the government arrived after this time. The threat of 'federalization' of the spill response due to improper removal actions by the responsible party was not a believable threat. The federal government did not have the funds, contracting capability, or organizational capability to move resources as fast as EXXON could.

The fact that the incident was a major disaster which would require an extraordinary response effort was recognized relatively slowly by all parties. Decision making during the operation was reactive rather than proactive--e.g mobilization of beach cleaning forces after the oil was ashore, establishing a federal and EXXON organization on Kodiak after the oil had reached the island. The organization and technology for the massive beach cleaning operation evolved--neither were considered in pre-spill plans.

The national contingency planning process has never fully resolved state--federal relationships during an oil spill of catastrophic proportions. The NCP, although allocating one seat on the RRT to the state, does not ensure (or require) that states set up a unified command system. The fragility of the state/federal and intra-state relationships was acerbated in the EXXON VALDEZ spill by a number of factors and ADEC had difficulty establishing its role as the leader of the state response and the state response organization did not work smoothly with the federal

OSC until well into the spill response. Factors which affected this relationship include the following:

-The Alaskan economy is heavily dependent upon oil revenues and, to a lessor extent, revenues from its fishing industry. The oil industry is controlled from "outside", the fishing industry is predominantly Alaskan owned. The spill was perceived as caused by 'outsiders' and the primary economic impact was on the prime local industry. The need to close or restrict fishing and to protect fish spawning areas ensured that the State Fish and Game had a major role.

-Alaskans had not anticipated that a major spill could occur and were truly outraged by the 'despoiling' of Prince William Sound, ensuring that the state response to the spill would be highly politicized. The values prized by Alaskans--self sufficiency, independence, small town & village living, pride in the pristine wilderness--clash with the acceptance of the economic giant of the oil companies.

-The State of Alaska is a major landowner in the Prince William Sound area, ensuring that the Department of Natural Resources had a key role in the response effort.

-Native Corporations are major landowners in the Prince William Sound area and native villages rely on fishing for subsistence. This made both the political and social impacts of the spill more complex.

-Coordination between State Emergency Services and the ADEC during a major environmental disaster had not been resolved prior to the incident.

The area of contingency planning should be examined closely in the wake of the EXXON VALDEZ incident. We must be able to create, equip, and manage organizations which are capable of effectively and efficiently dealing with major oil spills.

4. Response Tactics

Once the EXXON VALDEZ incident occurred, a 'window of response' lasted about 72 hours during which effective mechanical removal of oil from the surface of the water was possible. Dispersants and burning techniques were also effective at the leading edge of the spill. This window ended Sunday night when the oil was emulsified by a storm. After the initial storm on Sunday night, there was 'a window of lessor opportunity' of about a week, during which there was still a significant amount of free floating oil which, although highly emulsified, may have been susceptible to mechanical pick up. This period also provided the optimal time for preventive booming of sensitive areas.

The amount of resources available on scene, accessible in the region, and in the logistics pipeline (booms, skimmers, dispersants, burning agents) were not adequate to take advantage of the first 72 hour 'window of opportunity', regardless of who was in charge or what organizational arrangement was used. A more effective organizational and command structure and a more responsive marshalling of resources might have made a difference during the week long period of lessor opportunity. During this period, less than 5 % of the oil was contained, removed, dispersed or burned. With an 'optimal' response another 10-20% of the oil may have been prevented from reaching shore--but the amount of shoreline affected would not have been significantly different. After the first 10 days, little else could have been done to reduce the amount of oil that hit the beach, although protective booming could still have influenced where the oil hit. The spill and its response occurred under relatively favorable weather conditions. During periods of severe weather in Prince William Sound, no amount of equipment, dispersants, etc would keep the oil from the beach.

The salvage of the EXXON VALDEZ, although not pre-planned, was expertly conducted in a coordinated effort by EXXON, CG Marine Safety Office VALDEZ, CG Pacific Strike Team, and salvors contracted by EXXON. This successful salvage prevented up to a million additional bbls of oil from entering Prince William Sound.

As stated above, response tactics were severely constrained by resource constraints and by the lack of federal/state/industry coordination. The incident did, however, show that the capability of mechanical containment and removal technology is still very limited and that the policies and procedures governing the use of dispersants and burning agents have not been adequately resolved nor have tactics for their use been fully developed.

5. Beach Cleaning Technology and Environmental Impact

Possibly one of the more frustrating aspects of the EXXON VALDEZ incident was that many of the actions taken to clean the beaches may have actually had a negative impact on the environment. While some amount of beach cleaning is desirable, there is no consensus on how much is the right amount. Similarly, there is no agreement on what technology or procedures are most appropriate. Many technologies and procedures used in the Alaskan beach cleaning operation were adopted from other industries on short notice. There is mixed reaction to the process of using high temperature, high pressure, hot water, repeated ten or twenty times, to clean a beach. A comprehensive analysis would consider the pollution caused by the army of more than 10,000 people and hundreds of boats and planes in the process of beach cleaning.

6. Waste management

The Exxon Valdez oil spill resulted in tens of thousands of tons of oil soaked material that needed to be disposed of. Much of this material was biodegradable, such as floating logs or seaweed on beaches. Typically, materials picked up were biodegradable and placed in plastic bags. Most of the waste was placed in a hazardous waste land fill in Arlington, Oregon, one of only two hazardous waste landfills in the U.S. Pacific Northwest. (The government did allow some incineration on barges towards the end of summer).

There are many lessons to be learned in waste disposal management from the EXXON VALDEZ incident. The Environmental Protection Agency could promulgate regulations for ocean incineration, a process that has dragged on for many years. Federal guidelines for the disposal of oily wastes could provide better alternatives than the use of a scarce national resource (hazardous waste landfills). The development of biodegradable bags and the determination of the affect of salt water on the oily waste could aid the clean up process.

7. Risk reduction and response system degradation

All elements of the 'risk reduction' system established when the pipeline was built had never been reached or were degraded over time. Alyeska had cut its full time pollution response staff and assigned their responsibilities as collateral duties; the state accepted this contingent upon revisions to the contingency plan and increased response drills. Alyeska had never established an effective capability for skimming or storing skimmed oil. State pilots were allowed to disembark from tankers north of Bligh Island. The Coast Guard reduced its VTS watch from two persons to one. The Coast Guard did not establish a reliable system capable of monitoring ships while they were in the shipping lanes in Prince William Sound. Many of the Coast Guards vessel inspection functions have been delegated through contracts to the private American Bureau of Shipping.

The elements of risk reduction which were implemented in 1978/79 after the Argo Merchant grounding failed to prevent or to minimize the EXXON VALDEZ incident. Navigation safety regulations provided passive aids to ship master and watchstanders (e.g. radar, loran, fathometer, charts). There were no requirements for 'active' systems which would alert someone on the ship or in the VTS to the fact that the ship was standing into danger and that the passive systems were being ignored or had been disabled. Even if such systems existed, there is no maritime or legal tradition or precedent which would allow anyone to take control of the vessel away from the master. The creation of such systems would, therefore, require a departure from many maritime traditions. The segregated ballast protectively located did not prevent the opening of 11 cargo tanks on the EXXON VALDEZ. It is doubtful that the presence of a double bottom or a double hull would have prevented the escape of any cargo due to the impact of this extremely high momentum grounding, and may have complicated the salvage effort.

None of the recommendations for the federally funded development, purchase, or allocation of pollution response equipment which resulted from the 1978 investigation of the

ARGO MERCHANT incident were implemented. Research into methods of improving response technology (except for dispersants and burning agents) was sharply curtailed in the 1980s.

CONCLUSIONS

The direct economic costs of the EXXON VALDEZ oil spill will be great. The spill will cost EXXON about $5 million in lost oil, $20 M in salvage and repair costs, and about $800 Million in clean up costs. The potential economic losses to petroleum companies operating in Alaska are much greater: loss of ELF, Bristol Bay leasing moratorium, potential loss of Alaska natural wildlife refuge (ANWR) leases. The magnitude of the economic losses by the Alaskan people and the state of Alaska will be determined through extensive legal procedures but are estimated to be in excess of $1 billion.

Clearly, there is ample economic motivation to investigate the linkages and trade offs between risk reduction, contingency planning and pollution response and to invest significant resources in each of these areas. The authors contend that these linkages should be considered in policy formulation. For example, it is clear that risk reduction efforts must focus on scenarios for which counter measure and mitigation efforts are extremely difficult and costly. In the case of chemical releases, evacuation plans must be in place for areas/incidents where no effective counter measures exist. The risks associated with the transport of hazardous cargo are so great that the public's right to protection may outweigh traditional values such as the masters' control of his or her vessel and limitations of owner's liability. Increased usage of active versus passive traffic control and navigation aids may be warranted.

Catastrophic spills have occurred very infrequently, and have historically been geographically distributed throughout the world. Effective risk reduction actions will reduce the probability of their occurrence even further. Government and industry must be ready to deliver hundreds of millions of dollars worth of clean-up services anywhere in the world within hours of an incident. This means more than flooding the affected area with people and equipment. It means creating functional organizations, capable of making and implementing decisions and operating according to doctrine.

As was demonstrated this summer in Prince William Sound, much work remains to be done before we reach this ideal. The EXXON VALDEZ released a cargo of relatively non toxic crude oil into a very sparsely populated region. The environmental impact was significant, but the impact on human life and health was minor. The probability of a collision, ramming or grounding of a ship carrying chemicals in a port such as New York is small, but is certainly not zero. How effectively have we minimized this risk and what is our capability of responding to such an incident?

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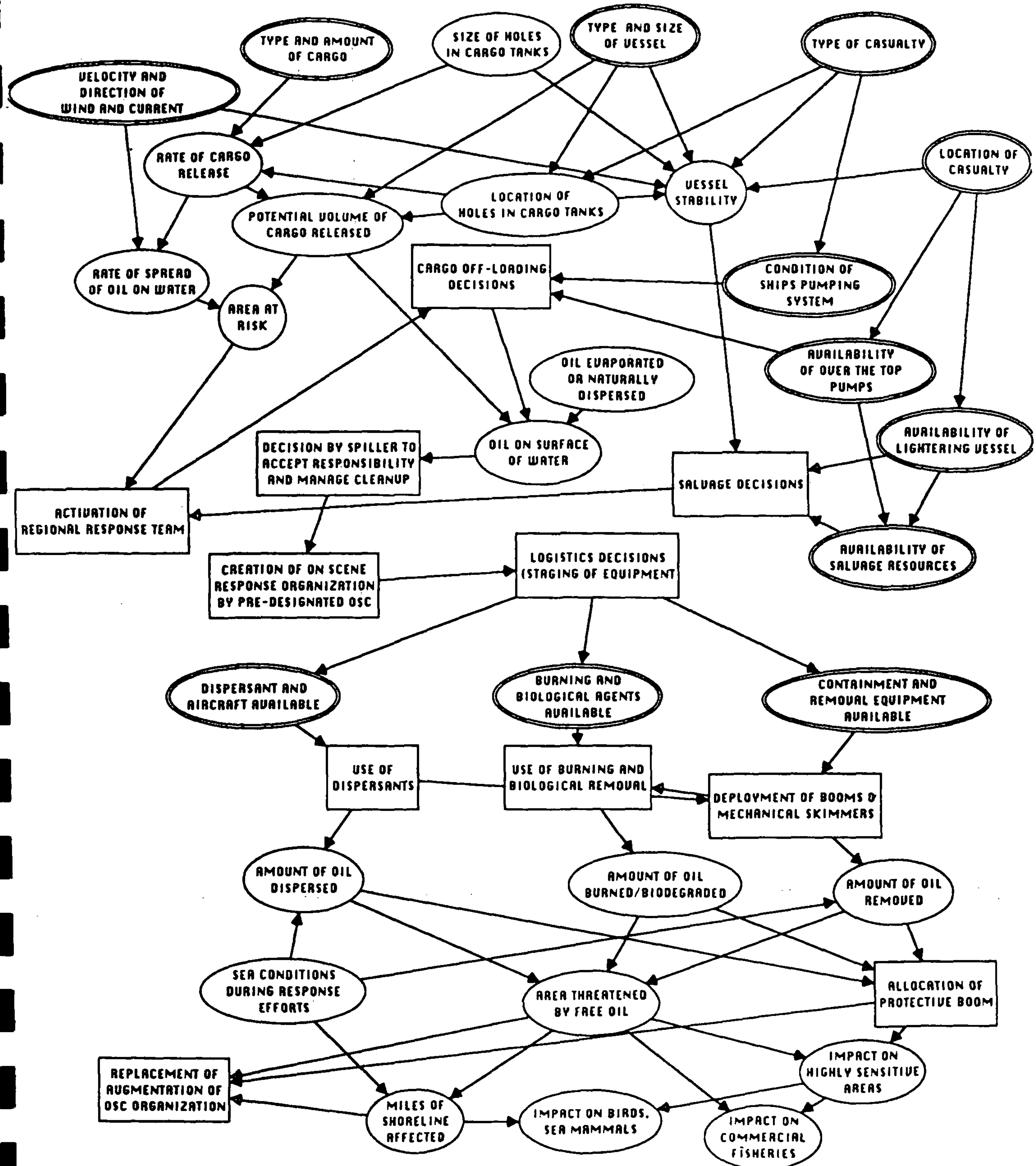

INFLUENCE DIAGRAM OF THE RESPONSE TO THE EXXON VALDEZ OIL SPILL