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The Relationship Between Public Policy and Risk Assessment in Tanker Design Regulation

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ABSTRACT

There is much room for improvement in the use of techniques involving risk assessment and technical analysis in the public policy decision making process as it applies to the marine field. The example of the regulation of tanker design, as mandated in the Oil Pollution Act of 1990, is utilized as a case study. Proper risk assessment for the complex tankers/waterway system requires a total-system approach, which is currently beyond the state-of-the-art, but the public demands an immediate response to what it perceives as a straight-forward problem and government must react. This paper discusses the further work needed in the areas of methodology, data bases, and communication/education to properly address these policy decisions.

INTRODUCTION

While techniques involving risk assessment and technical analysis are well respected and used in industry and academia, there often seems to be a dearth of such methodologies in the public policy decision making process as it applies to the marine field. This paper will use the example of the regulation of tanker design, as mandated in the Oil Pollution Act of 1990 (OPA 90), as a case study.

The tanker/waterway system is large and complex (and oil spills are a dynamic random-product). A valid assessment of risk for such a system cannot be made by analyzing a subset of the problem or by drawing conclusions from long-term oil spill statistics. Valid risk assessment and decision making requires a total-system model and analysis. When accidents occur, the public demands action, but the necessary tools to develop cost-effective solutions and to communicate the need and rationale for this process to the public do not exist. Often the solution in one scenario may not be the most cost-effective solution over all possible scenarios and vice versa.

Consider the Exxon Valdez oil spill in Alaska in 1989 which resulted in the Oil Pollution Act of 1990 that requires double hulls on all new tankers. Since Congress voted unanimously to pass this legislation, one might assume that it is a well thought-out law. One might consider the answers to the following questions:

- Will double hulls on tankers prevent an oil spill from an Exxon Valdez type accident?
- Are double hulls the best design to prevent or minimize oil spills in an Exxon Valdez type oil spill?
- Will new double hull tankers always spill less in accidents than the single hull tankers they replace?

The answers to all three questions are "No". There is no controversy among naval architects on this topic. First, a tanker weighing more than 200,000 tons at 12 knots hitting a reef will cause an oil spill no matter what commercial design is used. Unfortunately, many laypersons will be surprised after the first major oil spill in U.S. waters from a double-hull tanker that Congress didn't really "regulate" such spills out of existence. Second, to minimize an oil spill in a major "high energy" grounding, a design called mid-height deck would be more effective than a double hull. In the mid-height deck design, a horizontal, oil-tight deck through the cargo tank limits the outflow due to hydrostatic pressure. Most nations with the exception of the U.S., have declared that the mid-height deck design is equivalent or better than the double hull. Third, the maritime industry has determined that for tankers below 160,000 DWT, the least expensive double-hull design is one with only one tank across (rather than the normal two or three). When this tank is penetrated in a collision, more oil will spill than in a single-hull tanker with two or three tanks across. (U.S. laws and regulations requiring double hulls do not yet address the number of tanks across in the double-hull design.)

How can we be in this position where what might be thought of as the "obvious" objectives of OPA 90 are not being fulfilled. A simplified answer is "Too much emotion, not enough analysis." When seeing the pristine Alaskan environment covered with oil from the Exxon Valdez, the public demanded action. The double-hull design met the immediate emotion need. It is a quick "technology fix" that is easy for the layperson to understand. In addition, it should completely eliminate minor spills and reduce the impact of major spills. The cost to the U.S. of having double hulls on all tankers entering the U.S. is on the order of $700 million per year [1].

A MORE RATIONAL APPROACH

Since at least 80% of major tanker accidents (and probably the minor ones as well) are caused by human error [2], one might expect a formal risk assessment might have been made to determine the most cost effective way to reduce oil spills. In such a scenario, different "solutions" could be compared to see how many gallons of oil spills could be prevented by each solution (and at what cost).

However, it is clear that neither the industry nor academia was able to explain these issues to the general public or the Congress. Professors teaching the technical aspects of these issues had failed to communicate on a level that people with less specialized knowledge could comprehend.

To follow through with a rational approach to risk assessment, you need: a methodology, a credible data base, communication/education of the approach, and the political will to use it. The authors feel the political will can occur by itself if the other three needs are met.

METHODOLOGY

Once an accident has occurred it is too late to develop methodology, models, data bases, and tools to complete a total-system risk assessment, and select the most cost-effective response. The public demands that the government move more quickly than this. In such cases, the complexity of the tanker/waterway system forces industry, government and academia to focus on manageable pieces of the total problem, or to take a top-down statistical approach. It is difficult to draw cause and effect conclusions from statistics, particularly when data bases do not contain this type of information. Until there is a better understanding of accident mechanisms, any attempt to minimize accidents based on statistics alone is reactionary with questionable effectiveness. We must be working on a total-system methodology now if we expect to use it in crisis. This methodology should consider the basic physics and human factors of the problem and be sensitive to the impact of new regulations and technology.

The framework for a total-system methodology to assess tanker oil spill risk is presented in Reference [3]. The general structure of the oil spill model used in this methodology is illustrated in Figure 1. Simply stated, risk is the product of the probability of an accident and the consequence of an accident. Major disasters are rarely caused by any one factor. They arise from the enforceable concatenation of several diverse events, each one necessary but singly insufficient. Like the etiology of multiple-case illnesses due to resident pathogens, complex systems also breakdown due to resident latent errors. The challenge for this framework is to show how latent and active failures combine to produce accidents and to indicate where and how more effective remedial measures might be applied. The notional tanker risk calculation process is diagrammed in Figure 2. Once risk can be quantified, the cost/risk/benefit of various alternatives may be compared.

ACCIDENT PROBABILITY

Accident probability is calculated using Probabilistic Risk Assessment (PRA) techniques including fault trees, event trees and human reliability analysis (HRA)[4]. Fault tree analysis is very effective in analyzing complex systems that have multiple failure modes with physical and operational interactions, especially if the role of humans in the operation is a factor [5]. Fault tree analysis was developed for the aerospace industry for system safety analysis. Norman Rasmussen defined the essential tasks of a PRA in his safety study of the nuclear power industry [6]. This model follows his example. Human failure events are quantified using basic Human Error Probabilities (HEP's) that are modified by a series of Performance-Shaping Factors (PSF's)[4].

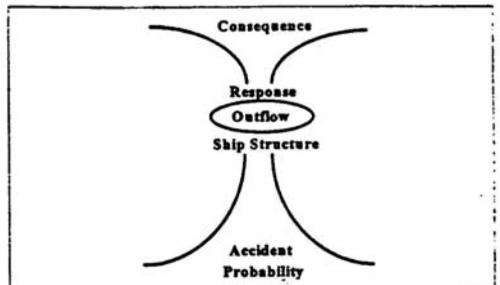

Figure 1 - Tanker Risk Model Concept

The fault trees become increasingly specific at lower levels where basic probabilities can be assigned reflecting individual error or other system failure. Standard HEP's are obtained from NUCREG/CR-1278, <u>Handbook for Human Reliability Analysis</u> [4]. Other probabilities are obtained from failure statistics, expert opinion and simulation studies. Event trees are used to further define tasks and develop fault probabilities. In this manner HEP's and other error probabilities are built up for each terminal event in the fault tree. Below this level performance shaping factors (PSF's) for the specific ship and port are used to adjust HEP's.

It is essential that important PSF's be identified to determine the effect external influences have on the basic HEP's. Table 1 shows PSF's from NUREG1278[4]. PSF's determine whether individual performance will be highly reliable, highly unreliable, or at some level in between. Using these generic PSF's as a starting point, specific ship and waterway shaping factors are identified. Their parametric relationship to the fault tree HEP's is determined by simulation and expert opinion.

The pending revision to the International Maritime Organization (IMO) Standards for Training, Certification and Watchstanding (STCW) and the new International Safety Management (ISM) Code are critical to the effective regulation, management, execution and monitoring of virtually all PSF's of concern to tanker safety. STCW and ISM certification and inspection records can provide an up-to-date status of human factors onboard ship and in the ship's management. This data can be used to update the total-system risk status for a specific ship for use by management or regulatory authorities.

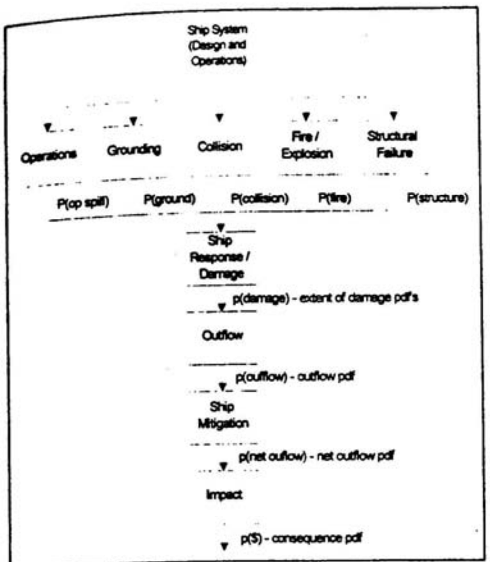

Figure 2 - Notional Tanker Risk Calculation

OIL OUTFLOW

Once probabilities for the major oil spill events (grounding, collision, fire/explosion and global structural failure) are determined, oil outflow is calculated using a probabilistic method based on the IMO "Interim Guidelines for the Approval of Alternative Tanker Designs Under Regulation 13F of Annex 1 of MARPOL 73/78" and a pdf is derived. This method calculates the probability of zero outflow, and values for mean outflow and extreme outflow for grounding and collision accidents using probability density functions (pdf's) for location and extent of damage.

One major shortcoming of the Regulation 13F methodology is that it does not consider the effect of structural design or crashworthiness on damage extent. The primary reason for this exclusion is that no definite theory or data exists to define this relationship. The solution of this problem must consider the interaction between local structural damage and global ship motion. The variety of structural details and potential accident scenarios makes this difficult. A methodology which considers crashworthiness should be sensitive to at least the basic parameters defining unique structural designs while maintaining sufficient generality and simplicity to be applied by working engineers in a regulatory content for a ship in a worldwide operation. It should not require detailed finite element analysis or be limited to a single accident scenario. The computational model developed at MIT by Professor Tomasz Wierzbicki under the Joint MIT-Industry Project on Tanker Safety is ideally suited to such an application [7].

SPILL RESPONSE

The options available for spill mitigation and cleanup include containment and elimination. Response to contain the spill is considered using a dynamic simulation model. Response is based on ship and waterway spill response assets. Probabilities are estimated using expert opinion. This calculation results in mean outflow after response.

Although the ship may have some onboard capability for containment, waterway assets, waterway management, and ship management are most important to the mitigation and cleanup function. Typically only 10-20% of the spilled oil is ever contained and recovered. The type and quantity of oil spilled, availability of personnel and equipment, environmental conditions and various human factors determine the effectiveness of the mitigation and cleanup effort. There is a room for great improvement in spill recovery and mitigation. Increasing recovery rates by 5-10% could significantly reduce spill consequences. Mitigation and cleanup should be actively investigated in the total system context.

SPILL CONSEQUENCE

The volume of oil spilled is not a valid metric for measuring the consequence of a spill. The impact or fate and effect of a spill is the correct metric and this is most conveniently quantified as a cost. There are five major categories of oil spill cost [8]: (1) commercial; (2) social and recreational; (3) ecological; (4) restoration; and (5) ship owners/cargo owners/insurance. Cost is extremely sensitive to the specific spill scenario. This model uses an average cost over many scenarios. Probabilities and pdf's are developed to identify potential spill locations in various waterways along primary tanker routes. A Monte Carlo simulation chooses the spill location and scenario based on these probabilities. The most recent Department of the Interior (DOI) Type A Damage Assessment Model is used to estimate primary restoration costs and compensation costs for various spill volumes (in U.S. waters). Regression analysis is applied to these results to calculate cost pdf's as a function of type and quantity of oil spilled.

DATA BASES

While methodologies that address such factors as human and organizational errors, such as the one described above, exist, they are rarely used. "The number one reason for this has been the almost total absence of any reliable data with which to do the modeling and calculations" [9]. Methodologies require data bases that explain "cause and effect" of previous accidents. Otherwise the methodology is nothing more than an academic exercise. Obtaining the right data bases is a challenging task. First, we have the "chicken and egg" problem. If no one is using comprehensive risk assessment methodologies, then why do we need the data (and how do we know what data we need). Of course, if there is not adequate data, it is impossible to apply the methodologies.

A researcher would like to have data bases with decades of information. The key assumption is that the "ground rules" for collecting the data have not changed over time. The U.S. Coast Guard's oil spill data base is the amalgamation of three different data systems: from 1975-1983 the Pollution Incident Reporting System (PIRS) was used, from 1986-1991 the Marine Safety Information System (MSIS) superseded the older system, and from 1992 until the present a modified MSIS is utilized. One must be careful in applying data across these time ranges.

One might think that everyone would be in favor of building comprehensive data bases; however, that is not always the case. In part due to accidents caused by pilots in U.S. waters, many persons have called for development of a rigorous relevant data base. The USCG's Merchant Personnel Advisory Committee and the pilots are against the idea of collecting such data on accidents "because the information collected might be used to pit one port against another" [10].

Table 1 - Performance Shaping Factors [4]

Procedures			Stressors		Internal
Situation Characteristics	**Job and Task Instructions**	**Task and Equipment Characteristics**	**Psychological Stressors**	**Physiological Stressors**	**Organismic**
Architectural Features	Required Procedures	Perceptual Requirements	Suddenness of onset	Duration of Stress	Training/Experience
Quality of Environment	Written or Oral Communications	Motor Requirements	Duration of Stress	Fatigue	Proficiency
Work Hours/Breaks	Cautions and Warnings	Control-Display Relationship	Task Speed	Pain or discomfort	Personality/Intelligence Variables
Availability/Adequacy of Equipment	Work Methods	Anticipatory Requirements	Task Load	Hunger or Thirst	Motivation/Attitude
Manning Parameters	Policies	Interpretation	High Jeopardy Risk	Temperature Extremes	Knowledge of Required Performance Standard
Organizational Structure		Decision-Making	Threats	G-force Extremes	Physical Condition
Actions by Supervisors		Complexity	Monotony	Atmospheric Pressure Extremes	Outside influences
Rewards, Recognition, Benefits		Narrowness of Task	Long, uneventful vigilance periods	Oxygen Insufficiency	Group Identification
		Frequency and Repetitiveness	Conflicts of Motives	Vibration	
		Task Criticality	Reinforcement absent or negative	Movement Constriction	
		Long and Short-Term Memory	Sensory Deprivations	Lack of Physical Exercise	
		Calculation Requirements	Distractions		
		Feedback	Inconsistent Cueing		

CHALLENGE FOR ACADEMIA[11]

Most college professors spend their time teaching to students that have chosen their area of specialty. Often the professor has been doing research on the leading area of specialization and is looking forward to sharing his or her new advanced knowledge with the students. In most colleges professors are also rewarded on their ability to perform research and publish the most sophisticated topics in their field.

Therefore, it is easy to forget that the students will often end up in environments where they must communicate their knowledge to people without their specialized backgrounds. In situations where the professor wants to effect a change in society, such as through the introduction of a new technology or with the passage of a new piece of legislation, the professor (or his or her students carrying out what they have learned) must be able to communicate the fundamental aspects of the topic to the general public, the media or the Congress. With these instances in mind the professor can plan in advance to be teaching for understanding on two levels: the basic level of understanding for the "layperson" and the more sophisticated student specializing in this topic.

Students today rarely comprehend that their specialized knowledge cannot be easily understood by the "layperson". Students, in effect, must be teachers to properly communicate their ideas. One by-product of the process of teaching for two levels of understanding is that the students will learn what it takes to communicate the specialized knowledge in their fields to "laypersons".

CONCLUDING COMMENTS

There is much room for improvement in the proper use of risk assessment in public policy decisions. More work must be done in the areas of methodologies, data bases, and communications/education. However, efforts have started in all these areas. While it will take considerable time and resources to effect proper risk assessments, one should remember that in the case of tanker design regulation, lack of such assessments have resulted in designs that are costing society hundreds of millions of dollars annually. It is the hope of the authors that these efforts to improve risk assessments will continue and will result in the political will to use such tools in public policy decision making in the future.

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