An Assessment of

RISK MANAGEMENT AND HUMAN ERRORS IN RECREATIONAL BOATING SAFETY APPLICATIONS

Marine Safety Foundation, Inc.

July 1999

Produced Under A Grant From
The Aquatic Resources (Wallop-Breaux)
Trust Fund Administered By The U.S. Coast Guard

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle	5. Report Date
An Assessment of Risk Management and Human Errors In Recreational Boating Safety Applications	July, 1999
	6. Performing Organization Code
7. Author(s)L	8. Performing Organization Report No.
Wayne W. Becker, A. James McKnight, Howard Kunreuther, Steven O. Kimbrough	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Marine Safety Foundation, Inc. 24 Briar Springs Road Orleans, MA 02653	11. Contract or Grant No. 1802.09
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U. S. Coast Guard Office of Boating Safety Commandant (G-OPB) U. S. Coast Guard Washington, D.C. 20590	Final Report July 1998 – July 1999
	14. Sponsoring Agency Code

15. Supplementary Notes

This is the first year overview report of an anticipated multi-year investigation.
This work was funded by the Aquatic Resources (Wallop-Breaux) Trust Fund.

16. Abstract

This report documents the results of a cooperative project to consider two related questions:

1) How can the concept of Risk Management best be employed in the Coast Guard's Recreational Boating Safety (RBS) Program? , and
2) How can human error as a cause of boating accidents be considered most fruitfully?

Both areas are productive near-term emphases, the first, in structuring and coordinating efforts to improve boating safety, and the second, in providing new insight on which to act on the major cause of boating accidents. The two subjects are linked and timely.

This report presents background particular to recreational boating safety and choices among risk management processes, developing some to the point of preliminary application. These include a structuring of the general transportation accident problem leading into a detailed structuring of the four boating accident categories that account for 80 – 90 percent of boating fatalities. The recommended risk management approach integrates consistent, thoughtful concern for making choices that provide the greatest improvement in boater safety (for a given expenditure of resources) together with an analytical framework for evaluating those choices. Elements of the decision framework are developed with particular attention to broad stakeholder participation and the identification of promising interventions to improve boating safety. Consideration is given to means of prioritizing Program activities in terms of risk reduction per unit cost. Applicable computer analytic tools are also evaluated.

The report also describes the development of a prototype system to obtain useful, credible information on the contributions of human errors to boating accidents, made possible by the new national electronic boating accident reporting system as compiled in the Coast Guard's Boating Accident Report Database (BARD.) A 300-item accident taxonomy is developed to support the coding of information in the narratives of about 1000 Boating Accident Reports (BAR's) from 1996. The resulting compilation demonstrates the utility of this approach and the potential for obtaining new insights (and quantification) of human-error accident causes. Further development is recommended to allow confident discernment of human-error categories involved in recent fatal accidents and to refine the process for integration into the national reporting system.

17. Key Words	
Risk, Human Error, Boating, Boating Safety, Marine Safety, Risk Assessment, Acceptable Risk, Decision Framework, BARD, Safety Data, Development of Alternatives, Risk Management, Computer Risk Assessment, Prioritization, Benefit/Cost, Budgeting, Transportation Accidents, Accident Taxonomy.	Unlimited

19 Security Classif. (of this report)	20. Security Classif. (of this page)	21 No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT F 1700.7 (8/72) **Reproduction of completed page authorized**

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IN
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Foreword

This report documents the cooperation of a number of organizations and persons to consider the usefulness of a risk management approach to recreational boating safety and how human-error causes of boating accidents can be better identified and weighed with a view toward their correction. Both areas represent opportunities, the first in enhancing Recreational Boating Safety Program effectiveness broadly, and the second in subjecting the whole range of human error accidents to a depth of causal analysis which was previously restricted to special cases.

This work was the subject of a cooperative agreement between the Marine Safety Foundation, Inc. and the U.S. Coast Guard Office of Boating Safety, under the Aquatic Resources (Wallop-Breaux) Trust Fund. The Marine Safety Foundation is a (Massachusetts) non-profit corporation dedicated to enhancing marine safety through research, education and coordination. Additional participants in the project represent Salutary Technology, Inc. (Moorestown, New Jersey), the Wharton School of the University of Pennsylvania (Philadelphia, Pennsylvania), Transportation Research Associates (Annapolis, Maryland), and independent marine and computer consultants.

This report is a connected compilation of works by several authors. The first two chapters (and sections of the Fifth) concerned with opportunities for application of a more deliberate risk management approach in the national boating safety program are the product of Wayne W. Becker of Salutary Technology, Inc., who managed this project, with the assistance of B. W. Thompson of Thompson Maritime, Inc. (Farmingdale, New Jersey) in developing the boating accident characterizations and other parts of Chapter II. The two major sections of Chapter IV related to the application of decision analysis to the boating safety problem are the products of Howard Kunreuther, Co-Director of the Wharton Risk Management and Decision Processes Center and Steven O. Kimbrough, Professor of Operations and Information Management at Wharton's. Chapter III, which concerns human-error sources in recreational boating, is the product of A. James McKnight of Transportation Research Associates working with Captain Anthony J. Pettit (of Lusby, Maryland.) They were assisted in the computer analysis on accident data by associates of the National Public Service Research Institute (of Landover, Maryland.)

The Marine Safety Foundation (MSF) appreciates the support it received from these and other participants and the personnel of the U. S. Coast Guard Headquarters Office of Boating Safety, in particular, its project monitor, Philip J. Cappel. Comments on this report can be directed to the MSF, Orleans, Massachusetts 02653 or the Coast Guard Office of Boating Safety, Washington, D.C. 20590.

Chapter I: Introduction and Summary

A. Executive Summary

This report results from a cooperative agreement between the U.S. Coast Guard (USCG) and the Marine Safety Foundation, Inc. (MSF). It documents consideration of two related questions:

- How can the concept of Risk Management best be employed in the Coast Guard's Recreational Boating Safety (RBS) Program?, and

- How can human error as a cause of boating accidents be considered most fruitfully?

This study indicates that both areas are productive near-term emphases, the first, in directing and coordinating efforts to improve boating safety, and the second, in providing new insight on which to act on the major cause of boating accidents. The two subjects are linked and are timely because of developments in their respective fields, immediate opportunities in the subject of boating safety and because of their abilities to positively impact each other. (Risk management provides a disciplined structure to consider human accident causes, and human accident considerations provide critical missing elements of the overall risk management picture.)

This report presents background and choices among these processes, developing selected means to the point of preliminary application. It describes the risk management concept and develops a basic structure and approach for applying it to the Recreational Boating Safety situation as it stands at the beginning of the Century. This approach integrates consistent, thoughtful, multi-party concern for making choices that provide the greatest improvement in boater safety (for a given expenditure of resources), together with a procedural framework for evaluating those choices. This framework incorporates disciplines of policy and causal analysis which are assisted by graphical and computer techniques, as further indicated in the Conclusions on page 3.

The report also describes the development of a prototype system to obtain useful, credible information on the contributions of human errors to boating accidents, made possible by a new national electronic boating accident reporting system as compiled in the Coast Guard's Boating Accident Report Database (BARD.) An extensive human factors accident taxonomy was developed. It was used to classify about 1000 accidents from a single year based on the computerized reports, including their previously unaccessible narrative sections. This illustrated the usefulness of this kind of analysis for improving understanding of the large proportion of boating accidents attributable to human error. This is also described further in the Conclusions.

In both cases, the report offers recommendations for refinements and extensions of this preliminary work to realize the substantial benefits these developments offer in terms of thoughtful guidance of choices of RBS Program content, and in terms of the potential for more capably assessing the human element in boating accidents using the information newly made available in the electronic database. These Recommendations are presented on page 4.

B. The Problem and its Significance

There were approximately 17 million recreational boats and 75 million "people participating in recreational boating" in the United States in 1998.[1] There have been between 709 and 1036 reported deaths resulting from boating accidents each year in the U.S. in the period between 1987 and 1997, tending toward fewer deaths in more recent years.[2] Significant injury, property damage and other economic loss is experienced on an ongoing basis. It is a fundamental part of the U.S. Coast Guard's identity and legislated responsibility to "... administer laws and promulgate and enforce regulations for the promotion of safety of life and property on and under ... [and to establish and operate facilities 'for the promotion of safety on, under, and over..'] the high seas and waters subject to the jurisdiction of the United States ..." (14 U.S.C. 2.) In furtherance of this general responsibility for marine safety, it has a specific responsibility to lead a national Boating Safety Program intended to "...improve boating safety and to foster greater development, use, and enjoyment of all the waters of the United States by encouraging and assisting participation by the several States, the boating industry, and the boating public in development of more comprehensive boating safety programs ...." (Public Law 92-75, the "Federal Boat Safety Act of 1971", hereinafter, the "FBSA.") There are a number of logical, traditional and legislatively required parts to this national program.[3] The question is how to discern and combine particular possibilities for improving boating safety to obtain the best overall outcome. This is where the two aspects of this study converge. The first, *Risk Management*, provides a concept and means to guide those determinations. The second, by increasing our ability to understand *human-error* causes of boating accidents, supports intelligent action in what is viewed as the dominant cause of boating accidents.

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[1] National Marine Manufacturers' Association, "Boating 1998." (See *www.nmma.org.*)

[2] U.S. Coast Guard Office of Boating Safety; Annual Boating Statistics publications or statistical releases. [Over the past thirty years, annual boating fatalities have approximated those in general aviation. (Source: 1998 Bureau of Transportation Statistics Annual Report, p. 78.)]

[3] These include a modest degree of regulation of boat design and construction; standards for vessel outfitting and safety equipment; vessel maneuvering rules and occasional operating restrictions; waterway marking; direct assistance to boaters in distress; educational activities; law enforcement, and planning, research, funding, coordination and facilitation of a national boating safety program in cooperation with the States and private organizations.

C. Summary, Conclusions and Recommendations

1. Risk Management is a productive concept upon which the Coast Guard can organize its Recreational Boating Safety (RBS) Program. In the context of the RBS Program, risk management is most basically a consistent and intelligent concern for the impacts of all its (actual and proposed) actions on boater safety. This focus and the will to act on competent deliberation with respect to it define the function. (Also note #2.)

2. The Federal Boat Safety Act (FBSA) of 1971 creates a national boating safety program and is the basis for the Coast Guard's detailed authority in this area. The Act is written in terms that we would view as establishing an integrated system safety or risk management approach for boating safety activities derived from it. The FBSA incorporates a concern that activities fostering boating safety should be balanced with a desire to advance the development, use and enjoyment of the public waters. Its several requirements for the involvement of State and private "stakeholders" in program decisions support this balance, and are consistent with contemporary governmental risk management outlooks.

3. The Coast Guard's actions, in cooperation with those of the States and other boating stakeholders, in implementing the FBSA – including the risk analysis and research done at the time -- were highly credible when viewed as an exercise in integrated risk management. The considerable and progressive increase in boating safety since then tends to bears this out.

4. Various techniques of boating safety problem analysis are cited or developed in this report. They tend to be oriented to the structuring and optimal resolution of particular safety questions in a logical and disciplined process of policy analysis. Graphics are produced which specify and organize the factors involved in 80 - 90 percent of fatal boating accidents, as an aid to further analysis. Specific computer analytic tools for supporting boating risk management are assessed and recommended. Together, these processes offer the potential for still greater improvement in boating safety, especially when leveraged by the concerted activities of other stakeholders.

5. The electronic submission (mostly by the States) of Boating Accident Reports into a recently-developed computer-accessible national Boating Accident Report Database (BARD) allows accident analysis that provides a higher degree of discernment and easier, more complete comparison of accident causal data than was previously practical. A key feature of this system is the inclusion of a reporting officials' narrative summary of the accident as text within the electronic accident report file.

6. Recognizing that human error underlies the preponderance -- variously estimated as from 65 - 80 percent -- of boating accidents, the Study Group developed an extensive (about 300 item) structured breakdown of behaviors required to operate a boat safely. This taxonomy was refined through several cycles of use to code the causes of accidents revealed in the narrative summaries of about 1000 cases from the 1996 BARD. This demonstrated the potential for much better identification and quantification of human-error accident causes. This kind of analysis can lead to improved understandings of accident sources and abilities to conceive effective possibilities for intervention. The text contains (data-limited) reviews of some human-error boating situations as indications of the potential of this process.

7. There is opportunity for the Coast Guard to improve RBS risk management by several means, including the following near-term recommendations:

a.) - making an organizational commitment to the risk management outlook of item #1, above: the affects of all proposed policies and actions are weighed in terms of their impacts on boater safety. (Section II.A.)

b.) - developing and obtaining consensus on a version of the concept of publicly "acceptable risk" as an effective guide in structuring the boating safety Program. (Section II.A.1.)

c.) - developing the ability to measure organizational options in terms of the improvements they offer to boater safety per unit of total cost involved. (This will allow prioritization of Program changes in terms that are consistent with its basic commitment, improving Program effectiveness over time.) (Section V.B.2.)

d.) - continuing to evaluate how others are approaching risk management and consistently engaging the wider boating community in risk-based terms. (Section II.A.)

e.) - refining and field-testing the human-errors taxonomy developed under this project for incorporation into the national boating accident data collection structure. (Chapter III.)

f.) - coding and evaluating three consecutive years of fatal boating accident data and one full year of non-fatal accident data to provide a better basis for human-error causal analysis. More detailed models of human-error causal relationships should also be developed. (Chapters II and III.)

g.) - reviewing boating accident information and analyses to assess the relative risk presented by, and priorities to be accorded addressing, various boating hazards. (Section V.B.)

h.) - performing detailed hazard analyses on a limited number of high priority -- i.e., high impact and current policy concern or opportunity -- subjects, incorporating new human-error data sources where helpful. (Section II.C and Chapter III.)

i.) - developing facility with new tools and process of risk analysis, including:
- Accident data and hazard analyses (Chapters II, III, and IV)
- RBS policy analysis (Chapter IV)
- Computer analytic capabilities (Chapter V)
- Risk-based Program analysis (Chapter V.)

j.) - forming relationships that support and extend this kind of risk management outlook and competence. Fields of activity include the following:
- Other safety activities of the Coast Guard (where a new mechanism for cooperative interchange of risk management information is recommended.)
- Other elements of government (especially transportation and regulatory.)
- Other institutions of the boating community.
- Professional and academic associations that enhance this capacity.

Chapter II: Risk Management for Boating Safety

A. Fundamentals

1. *The Question of (Acceptable) Risk in Recreational Boating Safety*

In speaking of improvements in *safety*, one is usually interested in actions that might be taken to prevent *accidents* or reduce the severities of their outcomes. The fundamental *management* concern is to identify, among the many possibilities, and implement the actions that do that best, in *balance* with preserving boating's recreational character[4], and in view of the unresolvable *hazards* presented by much of the boating environment. In addition, that balance must be struck within the framework of our particular *democratic form of government*,[5] with the involvement of certain "stakeholders," through the consultative mechanisms and the other means established or allowed by the FBSA and other applicable laws. Thus, we have a complex question of substance, "How can we strike the best balance?", embedded in a social setting of prescribed processes and delimited means.

Let us consider what it means to "improve recreational boating safety." One intuitive notion of "safety" is a condition of being free from the possibility of a defined kind/level of undesired event, i.e., of the occurrence of an accident. It would represent a condition in which a boater[6] was not subject to the possibility of *harm*, carrying the meaning of the slogan "Safety is no accident." But, the idea of a state of absolute freedom from the potential for harm is not realizable anywhere in life, much less in transportation where control must be maintained of one's own speed/mass/movement with respect to other objects and their environments. It is even less so in the *marine environment*: energetic, changing, bounded, shared, only partly known in itself and in its interaction with a boat and its operators and passengers. Even if absolute safety were possible, in boating, it would almost surely involve separating the boater from the very aspects of his pursuit that make it "recreational." We are left with the realization that safety is not absolute, but relative. "*Risk*" can be seen as a measure of this lack of safety, encompassing notions of the *likelihood* and *magnitude* of adverse outcomes. The questions before us become: *"How much risk is acceptable (or tolerable) in the situations we are considering, and how can we best assure that level of risk, in balance with our other primary concerns?"* Answering those questions and turning the answers into direction for action is the task of *Risk Management*.

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[4] "... fostering greater development, use, and enjoyment of all the waters ...." (FBSA)

[5] This simple statement evokes a complex response of acceptable purposes, manner and extent of permissible means, identification of necessary or desirable forms of public involvement, creation of institutions at different levels of government and private endeavor, all with specific personalities, programs, plans, priorities and budgets.

[6] We are making a fundamental judgment that the proper focus of the boating risk management process is the people who stand in risk of harm, not boats, per se.

Addressing the first of these questions, what is "*acceptable* (or tolerable) *risk*" for recreational boating, in terms that are relevant to a national boating safety program? In terms of the Coast Guard's responsibilities, alone, much of the answer is spelled out in the legislation[7] already cited, as supported by year-to-year decisions of its priority within a larger governmental setting. (This question might also be posed in relation to the States and boating organizations, but the Coast Guard's role is controlling in a systematic, national sense.) But, how much risk is acceptable to *the public* that we seek to serve?

If the boating safety legislation and on-going support for related Coast Guard action were solely functions of boating safety concerns, one could expect that they would indicate the degree of safety "the public desires." But these things are balances of forces that at best approximate the "public" desire. It behooves us, interested as we are in carrying out a basic responsibility to meet the public's needs, to develop a way of assessing the level of risk which is acceptable to the boating (and broader, affected) public, in order to best serve that public in proposing actions and priorities.

We can assess this level of *publicly acceptable risk* in at least three ways (in addition to the previously noted working of governmental systems):

1) - by *observing* the risks that members of the boating public <u>are</u>, in fact, willing to take by free choice among freely available options. (The resulting statement of acceptable risk might take the form of statistical observation, probably of some sophistication, to which a *value* judgment would be applied.)

2) - by *analogy* to the level of risk that similar members of the public are willing to take in pursuit of similar interests. (This might involve surveys of risk in a variety of recreational pursuits, various modes of transportation and jobs in the marine industry. We could expect a sufficient analysis of this sort to establish a plausible range of public tolerance of risk in which different kinds of boating activity could be positioned.)

3) - by *argument* from the ways in which different elements of our political/social system relate to boaters who can reasonably be expected to tolerate certain defined levels of risk, differing depending on their knowledge, intentions, fitness and other relevant criteria. (These criteria might distinguish, for example, between the greater need for the public to assure the safety of a novice, than a highly-experienced boater who has a greater ability to evaluate risks and protect himself.) Thus, one could argue that everyone should be free to do what he wants, until doing so interferes with the rights of others to do the same, including their having to bear various social costs. This would lead to the specific, limited rationale for government support of safety in each class of acceptable risk. (The arguments are similar in kind to those that might be used to assure appropriate levels of safety in commercial <u>vs</u>. experimental aviation.)

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[7] The requirements as to purposes and processes imposed by the FBSA and other elements of the national setting will be considered in the next two sections, II.A.3 and 4.

This is a manageable and illuminating process that has the practical potential of rationalizing actions, actors and priorities in boating safety.[8]

In practice, we can expect to benefit by combining these (four) approaches, subjecting the entire process, but, most critically, its proposed results, to deliberation in appropriate professional and public venues.[9] Since the concept of acceptable risk answers the question "What is (the right amount of) safety?" in relation to recreational boating, it lies at the core of our interest. This question has rarely received the systematic treatment necessary to realize its considerable practical value.

2. *Risk Management as an Outlook and a Process*

Risk management has a long history. (Picture the art of the successful military or political practitioner in ancient times, attempting to control the risks, to assure the success of his endeavors.) It is a subject that all people deal with, more or less successfully, on both a thoughtful and an intuitive level in many aspects of their daily lives. (Picture personal decisions of when to cross a busy street, where to invest, who to trust, whether to challenge an opponent or engage in a game of chance.) It is an attempt to intelligently limit the harm to which one is exposed, trying to reduce "risk" -- the *probability*, of some (defined) undesirable event happening[10] -- to what seems an acceptable (or tolerable) level, as indicated above. It is a process of managing, i.e., trying to *control* the determinants of situations in ways most likely to fulfill one's purposes, given existing constraints. (Picture corporate decisions on how to minimize risk of loss and maximize profit or manage a complex project; or a government trying to minimize risks to the health or economic well-being of its population; or international agencies deliberating decision on complex issues of finance and trade, war and peace, or intergenerational effects of the acts of humankind upon its planet.)

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[8] This kind of analysis has been done by the Coast Guard in regard to some new areas of marine safety oversight. The USCG Headquarters (G-M) Underwater Safety Issue Study, the regulator portion of which was distributed for public comment in 1970's, provides an example of the methodical development this approach allows, from first principles to the specifics of the actions they justify.

[9] Understanding Risk: Informing Decision in a Democratic Society released in 1996 by the National Academy of Sciences emphasizes attention to public participation in government regulatory, and other, programs as a crucial concern of contemporary governmental risk management. The question is sometimes posed as one of the place of science in public affairs.

[10] On the many definitions of "risk": "Many dictionaries define risk as the chance of harm or loss. Many safety analysts define risk as the expected value of the product of consequences times probability, summed over all accidents or events. Some analysts state that this practice looses information and that risk is constituted of the uncertainties, the consequences and the probabilities. However, many social scientists state that risk includes a considerable number of other factors, many, of them intangible." (David Okrent; "Risk Perception and Risk Management: on Knowledge, Resource Allocation and Equity;"*Reliability and System Safety*, v. 59 (1998) p. 17.)

With beginnings in underwriting, public health, disaster planning and industrial safety, the process of Risk Management, like many others, has become progressively more "scientific" and professionalized in the latter half of this century. As a component of management science/operations research, it experienced considerable development in association with and following World War II. Growing from applications in logistics and engineering reliability, pushed by cost-effectiveness analysis as part of DOD's "systems approach," it was given a boost by the "systems safety" requirements of aviation, space and nuclear power programs, and enhanced by synergies with ever more sophisticated business analysis. In recent years, it has seen considerable growth and refinement in relation to the spectrum of public programs related to the environment, toxicology, and public health and safety . Existing and proposed requirements for broad cost-benefit analysis of Government programs with large public effect may carry this development further. Certain requirements for risk or safety analysis have been formalized by the military, DOE, NASA, EPA , OSHA, FDA and other agencies. Others, typically consensus standards, are published by a variety of professional and national and international standards organizations, for example, the American National Standards Institute and the International Standards Organization, and are given force by economic concerns including insurance and product liability. Some of these processes have become highly developed and structured in their own realms, so that, for example, a phrase like "to do a risk analysis" has a very particular meaning within those fields.

There is considerable insight that can be transferred from these structured applications to our own.[11] However, we believe that our purposes will be best served, at this point, by viewing Risk Management as *a professional outlook* characterized primarily by a continuous, deliberate process of focusing on the safety needs and outcomes of a variety of (boating) situations and the value of different means of addressing them. It is this focus and quality of continuity and deliberation which we feel best defines Risk Management for our purposes. It provides the basis for a productive, systematic structuring of all boating safety functions: our attention is first drawn, and continually returns to, the question of the affects of possible actions on the safety of persons involved in boating. We remain committed to answering those questions by the best means available, both systemically, and for the particular problem at hand[12], valuing precedent and consistency, in their place.[13]

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[11] For example, the general approach of the quality and environmental managements standard families of ISO 9,000 and 14,000; and DOD's MIL-STD-1629A, "Procedures for Performing a Failure Mode, Effects, and Criticality Analysis." Or, more specifically, the G-M Risk-based Decision Making Guidelines, or the ISM codes accepted under SOLAS.

[12] Please refer to Section IV.A for a general, systematic approach to boating safety decision analysis.

[13] Consistency should be judged forthrightly on its value to all concerned. It often has value, both in terms of substance and human relationships, but this should be assessed as any other characteristic.

Here, then, is the concept of "risk management," that we set out to assess. It is an *intelligently implemented desire to limit potential for harm.* It is a deliberate, thoughtful and systematic attempt to (make and implement decisions that) keep bad things from happening in a situation toward which one's interest is directed. Putting aside other possible meanings, as it applies to the safety of a *system* or its activities, it is fundamentally the outlook and intention (to be carried through to action) of systematically assessing and controlling the factors that determine whether the activity in view will be conducted without unacceptable likelihood of undesired events occurring. We can see elements of the Risk Management process emerge from the foregoing characterization:

a. Our focus on an activity associated with a particular defined system.

This activity characterizes the functioning of a particular system in which we are interested. The system can be composed of people, things, knowledge and processes. (It could be defined as a boat and its occupants.) While the activity of the system may be static or changing, and associated with other systems or activities, the system of interest is, itself, uniquely defined to distinguish it from the elements of its environment.

b. An environment in which the system exists and in which its activity takes place.

The system on which we are focused is contained by *its environment*. There may be many elements of the environment. The elements may also be static or dynamic (or potentially so) and they may be physical, personal, institutional and intellectual/informational, or, usually, a combination of these.

c. Interaction between the system and its environment (or within the system itself) such that there is a realization that the activity has the potential to "go wrong."

Certain *hazards* are recognized. These are potential sources of harm of interest in the particular case (of system, activity, environment and viewer/manager.) The harm might involve the injury, illness or death of a person. It might also involve negative economic, social or environmental consequences. Hazards can be recognized through experience (which may be direct or indirect, as through reports), from the logic of causal relations inherent in situations, and by analogy to similar "known" situations. This realization often has a quantitative aspect: an awareness of the existence of degrees of harm and differences in likelihoods of occurrence.

d. The (at least implied) appreciation of an applicable standard.

One considers his foundational values (and any imposed standards) in determining what is harmful in a situation and the level of risk of harm that one can accept.[14] The public "acceptance of risk" concept previously mentioned is one such standard, as are laws and

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[14] A quantitative example might take the form: "One chance in a million of serious injury is acceptable to us in this kind of outing."

technical standards. There are often unspecified personal and corporate thresholds for what is an unacceptable risk of harm that function as de facto standards.

e. A hazard assessment activity which is the deliberate and thoughtful.

There is a real concern and attempt to understand what is at stake in the situation and the factors upon which that depends. (For example, see the boating accident scenario characterizations of Section II.C.) The hazard analysis, itself, generally proceeds by trying to determine the causal relationships among the factors that define and contribute to the accident. There are a number of graphical techniques that can contribute to this deliberation, forcing decisions as to the identity and progression of causes that can lead to the realization of harm. (Some are shown in the material that follows in this Chapter, and in Section IV.B which discusses aspects of techniques such as influence diagrams and variations of hazard flow diagrams.)

Having specified a logical flow of the elements of a potential accident, the analyst can focus on the individual steps involved, characterizing them and their constituents and relationships, seeking understanding that allows the design of *interventions* that block the stream of events leading to an accident, or that reduce its severity. Figure II.A.1, on the following page, is such a diagram, reproduced from an earlier boating safety study[15], that portrays boating collision causes. (Other examples appear later in this chapter.) This analysis can be qualitative (as in the preceding discussion) or quantitative. In quantitative hazard analysis, one is usually trying to develop definite expressions of the likelihood that elements in a chain of events will transpire, in order to estimate the costs and efficacy of different possibilities for intervening in the accident process. This allows selection of the best process for intervention in terms of "benefit" and cost. (Performing these analyses is a discipline in itself, involving specialized knowledge and abilities.) Depending on the problem, quantitative hazard analysis can be quite expensive, requiring the development of mathematical models and source data, so that the manager must choose the depth of analysis that a problem (or potential solution) merits. There are also a number of semi-quantitative approaches which are useful for screening the possibilities to allow focus on the most severe problems and the most promising solutions, or producing relative rankings that lead directly to meaningful answers or decisions. We will refer to several techniques of hazard analysis in the material that lies ahead.

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[15] The diagram indicates cumulative collision causes in a study performed by Wyle Laboratories: Recreational Boat Safety Collision Research -Phase II; 1976; p. 75. The place of the Wyle studies are discussed in Section II.3. (Figure II.C.6 is another example.)

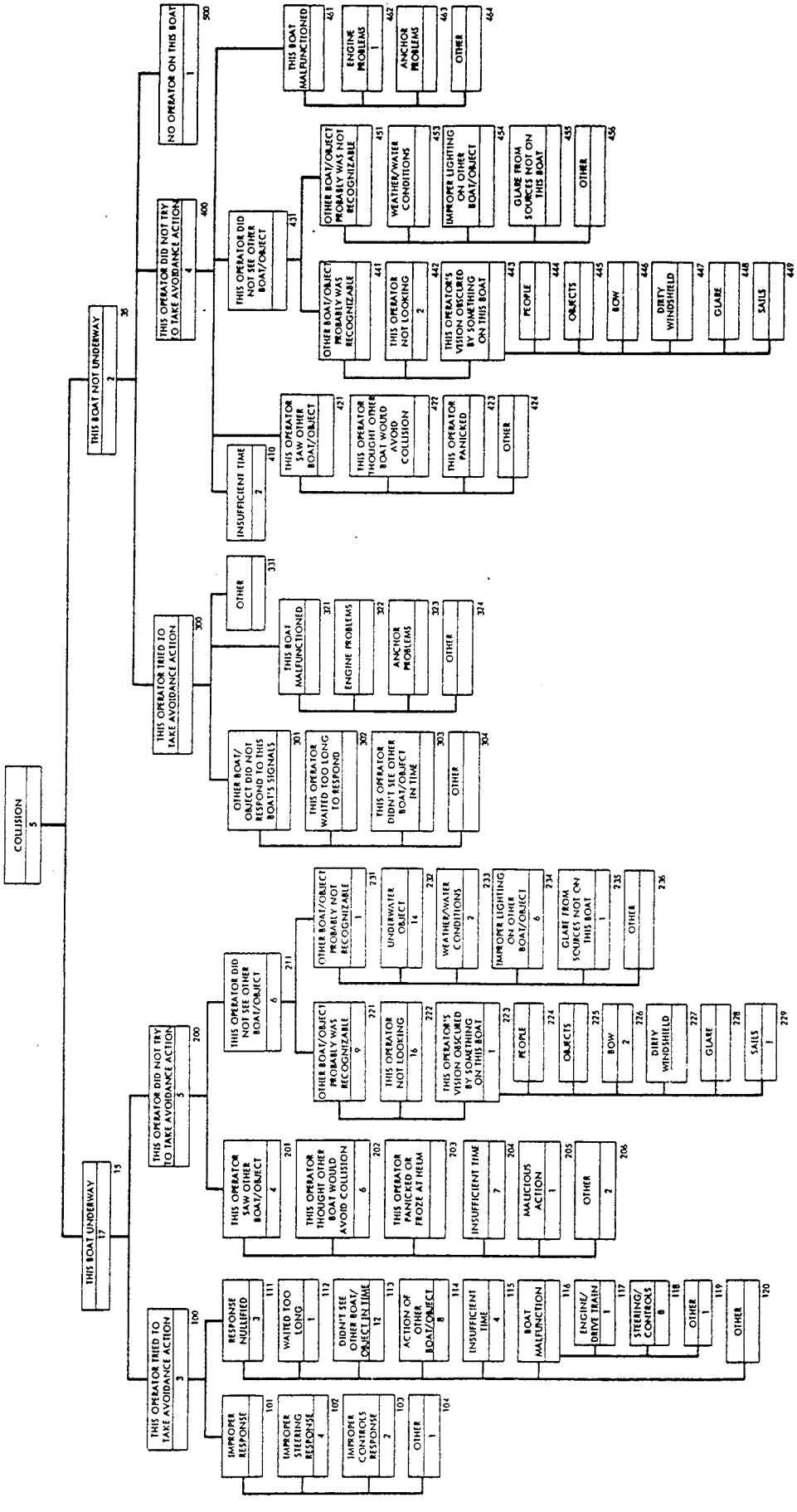

Figure II.A.1: Diagram of Causal Relations in Boating Collisions (Wyle Laboratories, 1976)

f. A determination (and realistic capacity) to intervene to prevent or reduce harm.

Without this will and capacity to act, either individually or as part of a wider community, the effort expended in analysis effectively has no outcome in the here and now. This is the crux of the *management* part and drives both the analysis and transfer of solutions into use. Based on prior analysis and, possibly other elements of the situation, one decides what is best to do and sets about doing it. Detailed review of proposed solutions is indicated, because of assumptions and simplifications of reality that are usually involved in the technical analysis of complex problems, as well as the possibility of bias toward a particular approach or solution. "Expert opinion" can provide a source of ideas for unrecognized alternatives, a useful reality-check and integrating value. A management approach that routinely questions analyses and incorporates outside review is useful in providing correction or confidence in an analysis, as well as in communicating its reasoning and results to facilitate the decisions and actions, which, in the end, are its purpose. In formal or standardized risk analysis[16], this process may be dealt with in terms such as these, indicating their duration on a rough time scale:

- Risk Communication ---------->
  -Hazard Identification ---->
    - Risk Assessment ----------> (Increasing time ---->)
      - Risk Characterization -------->
        - Risk Reduction Analysis ---->
          - Intervention ------->
            - Impact Analysis ---------> .... and iterative <>)

Figure II.A.2: SOME COMMON TERMINOLOGY (AND RELATIONSHIPS IN TIME.)

While terms such as these (and individual process identifications) are well-defined within certain use-settings, even established in codes and regulations, there is considerable overlap and use of different terms from one setting to another. We recognize the validity of the many of the specialized risk management techniques within their settings, but have chosen to try to move the discussion closer to the common language of problem solution and boating safety, to blend risk considerations into a model for boating safety decision-making. In the next section, we will consider the very credible heritage of formal RBS risk management which provides confidence in this stand.

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[16] The following websites contained definitions and descriptions of several approaches:
- *www.sra.org* (This is the Society for Risk Analysis; see the Glossary),
- *www.uscg.mil/hq/g-m/nmc/ptp* (This is the USCG G-M "Prevention Through People" program.)
- *http://riskcenter.doe.gov* (This is USDOE's Center for Risk Excellence.)
- *www.rdc.uscg.mil* (This is the USCG R&D Center. Click on research and see risk and human factors programs.)
- *www.JBFA.com* (JBF Associates is working with the USCG R&D Center on an Integrated Risk Assessment Project.)
- *www.riskworld.com* (A good overview site. Note the links to "Understanding Risk Analysis.")

3. ***Recent History of USCG Recreational Boating Safety Risk Management***

As previously noted, the Recreational Boating Safety (RBS) Program is founded on the Federal Boat Safety Act of 1971. The FBSA generally requires "the Secretary of the Department in which the Coast Guard is operating" to take a systematic view of what is good for boating safety,[17] in consort with the States, industry and other interests, and in balance with assuring the benefits of participation in boating to the public. The language of this statute is largely the language of *system safety* and risk management, requiring a focus on the affects of the Program on boater safety, reliance on *rational* analysis and the establishment of requirements. The following excerpts from the FBSA's statement of purpose attest to this:

- *"...the purpose of this Act (is) to improve boating safety and foster greater development, use, and enjoyment of all the waters... (with all interests cooperating in) development of more comprehensive boating safety programs... creating more flexible regulatory authority...a higher degree of reciprocity and comity among the several jurisdictions and closer cooperation and assistance...."*

This approach is further characterized by the wording in implementing sections of the FBSA:

- *"...may issue regulations establishing minimum safety standards ...shall be reasonable, shall meet the need for boating safety, and...(preferably be stated) in terms of performance... (the subject) includes, but is not limited to ...finds there exists a boating safety hazard so critical as to require (exceptional action)... shall consider the need for and the extent to which the regulations or standards will contribute to boating safety ...consider relevant available boat safety standards, statistics and data, including public and private research ...(allow exceptions if) boating safety will not be adversely affected... (prohibit operation of a vessel) in a negligent manner so as to endanger the life, limb, or property of any person... (requiring special provisions) to meet the need for boating safety and (allowing termination of) unsafe conditions (and requiring) immediate and reasonable steps...necessary for the safety of those aboard... (requiring notice of defects that) create a substantial risk of personal injury to the public... (and so forth through many other examples.)"*

It is seen that the language of the FBSA expresses the basic outlook and requirements of a risk management approach. In the next section, we will see that it also incorporates many of the relational characteristics encouraged by contemporary risk management understanding.

The Coast Guard's response to this legislation was to setup an integrated national boating safety program that included boat construction and equipment standards, inspections and testing; field boating law enforcement units; coordination, development and support of enhanced state programs; expanded educational programs; upgraded Auxiliary support, and a systematic research and development program to assist in getting the most safety benefit out of this effort in

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[17] It also served as a vehicle for carrying forward some highly specific regulations developed under previous legislation which has tended to diminish its systematic emphasis.

the spirit required by the FBSA. Initial post-FBSA Program planning, research, coordination and implementation formed a continuum of activity directed toward improved boating safety.

Research supported Program planning and the reasoned selection of means for enhancing safety, as required by the FBSA.[18] This research included scores of individual projects organized to investigate and develop the general direction and details of an integrated safety program. Groups of projects assessed the causes of different classes of accidents employing a mix of statistical, observational and logical approaches. They evaluated alternatives and proposed solutions in the forms of design standards, regulatory approaches, educational strategies and supportive infrastructure for improved safety.

A primary emphasis in this approach was what might now be identified as a *risk analysis* track, operating at an overview level and a series of individual risk management studies connected with particular problems and options. Much of the overview work was conducted for the Coast Guard by Wyle Laboratories, Inc. of Huntsville, Alabama. Detailed studies, often involving engineering assessments in the case of boat regulatory options, were carried out by a number of institutions. The research reports cited in the Bibliography to this chapter provide an indication of the scope of this activity. In relation to our interests, it included, for example, accident cause identification studies, boater decision-making studies, investigations of boater fatigue and environmental stressors, development of "regulatory effectiveness assessment methodologies," considerations of the effects of alcohol on operator performance, control station design, visual signaling, effectiveness of aids to navigation, design options and effectiveness of PFD's, and studies of a range of alternatives for regulations and educational approaches. Overall, this represented a very credible and integrated risk management approach. The results of many of these studies are still quite useful. For the time, some of this work led its field in aspects of naval architecture and other technical disciplines, and aspects of psychological/sociological research connected with population surveys, investigation of physiological/psychological stressors, analytic consideration of "the value of a life" and investigations into how perceived risk affects behavior, areas now seen as being in the realm of "risk analysis."

The Wyle risk analysis work extended through the 1970's in a lengthy series of studies. An outside decision analysis group was contracted to summarize and simplify the results for use by Program analysts. The result was a source book on Analysis for Programmatic Decisions.[19] This reference remains a valuable guide to RBS-specific needs assessment, performance prediction

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[18] A description can be found in the report "Recreational Boating Safety Research and Development Program Perspective 1977-1981"; USCG HQ (G-D); c. late 1970's, early 1980's. RBS research project listings are also available from USCG Headquarters.

[19] Mandex, Inc. and Decision Science Consortium (L. Greenberg et al.); Recreational Boating Safety: Analysis for Programmatic Decisions; 1984.

and evaluation, multiattribute utility analysis[20], and resource allocation methods. It presents basic concepts and techniques of risk-based decision analysis in application to RBS subject matter in understandable fashion. (We will return to decision analysis as a major component of risk management of interest to RBS Program management in Chapter IV.) An annual grant program for selected boating safety activities of national nonprofit public service organizations has been the primary vehicle for Program research more recently. This research (comprised, again, of scores of projects) has had application to boater education, statistics and selected problems, including aspects of risk analysis.

There has been a striking and sustained trend in the reduction in the annual number of boating fatalities accompanying the implementation of the changes that resulted from this process. This trend has continued into the present, despite a general reduction in Program resources over the intervening years, probably indicating the good resulting from the assertive risk management approach followed after enactment of the FBSA.

4. *The Setting of USCG RBS Risk Management*

The setting within which the Coast Guard must carry out its risk management function for recreational boating is unique and determinative of how it must/should/can best carry out that function. This setting is composed of the Coast Guard's particular place in the U.S. Government, the nature and organization of boating activity in the United States and the relation of the two. Some basic demands of this situation and interplay were identified in Section A.1 in the process of considering a notion of "acceptable risk" appropriate to boating safety. We will now briefly consider some aspects of the institutional setting in which boating risk management takes place that characterize the process and introduce limitations and opportunities.

The Coast Guard has a general responsibility for marine safety in the United States, of which the FBSA (and some previous legislation) lay the foundation for its boating safety functions, as developed in the preceding discussion. The Coast Guard's responsibility for marine safety extends to U.S. commercial shipping and to all users of U.S. waterways. This includes regulation of U.S. commercial vessel design, construction, maintenance, inspection, manning and use, and the assurance of foreign vessel compliance with appropriate international standards, as well as U.S. rules for the use of its waterways. It also extends to providing services that make marine transportation safer and more efficient, for example, systems of channel markings and electronic aids to navigation, and search and rescue services to assist persons in distress on the water. The Coast Guard organizations that perform these functions provide information and

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[20] A way of valuing choices where a number of determinants come into play; uses a scoring matrix to sum the weighted indications of value for each of a number of alternatives for comparison.

assistance of value to the boating public, coordinated with, but separate from, the Coast Guard office that has immediate responsibility for recreational boating safety. The opportunities provided by coordination and the need to balance solutions for *diverse marine users* are apparent. There are also administrative structures and approaches that overlap, for example, there is a Marine Safety Information System and an operational reporting system from which Search and Rescue data can be abstracted that have the potential to compliment BARD data in understanding some boating accident-related phenomena. Further, the Directorate for Marine Safety and Environmental Protection (G-M) overseeing commercial vessel safety possesses a wealth of relatively sophisticated marine safety technical and regulatory competence which is directly applicable to many boating safety problems. (Indeed, there are a number of cross-over concerns for which there are well established relationships between these organizations, for example, in the area of safety equipment (e.g., PFD) certification.) G-M has oriented its entire business plan toward "risk-based decision making," declaring "Risk management is our business."[21] For several years, G-M has been developing an intentional risk management outlook and process across its organization[22]. This program has, itself, developed a strong component on human-error accident causes known as "Prevention Through People."[23] G-M (and representatives of wider Coast Guard operating programs) have research on-going in this area. Some is being done at the USCG Research and Development Center. This includes both human factors and general risk management work. An example of the latter is a program to develop an Integrated Risk Assessment methodology for application to Coast Guard operating units.[24] There is substantial opportunity for increase of shared value with these programs and their research.

The broader Federal government also influences potential boating risk management approaches. There is transferable information from other activities of the Department of Transportation, collecting statistics and investigating and analyzing accidents and their solutions in all its modes. Many are of interest by analogy (both in what they are and how they are treated.) USDOT has maintained a decade-long human factors research emphasis. (DOT, as the Coast Guard's (peace-time) parent agency, also represents a step in the exercise of control over policy, planning and budget that proceeds through OMB, the President and Congress, in the annual appropriations process, as well as on special issues. Internal government programmatic competition for available resources affects boating safety programs, as well.) In recent years, the

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[21] Comdt. (G-M) letter 16010 of 15 January 1997. Ref: CI 16000.2 (series), "Business Plan for Marine Safety and Environmental Protection."

[22] See "G-M Guidelines for Risk-Based Decision Making." This G-M publication is a very useful source of background information on risk management applied to marine safety.

[23] U.S. Coast Guard; "Prevention Through People Quality Action Team Report;" USCGHQ (G-M); 1995. (Also see the PTP Internet site, linked to G-M's, linked to *www.uscg.mil.*)

[24] See Integrated Risk Assessment (IRA) Manual produced by the USCG R&D Center (based on work performed by JBF Associates, Inc.) in 1998. This is another valuable source of background information. Some of its analytical techniques have application to RBS problems.)

environmental, health and safety programs of a number of agencies (viz: EPA, F&DA, OSHA, DOE) have driven "risk management" applications in Government, as well as requiring public use in their areas of responsibility. Public reaction to some of the effects of these has resulted in calls for a more deliberate balance between agency regulatory (and other) decisions and a broad view of their accompanying effects in society, particularly, economic. Recent legislation and internal Executive Branch orders have tended to broaden and strengthen requirements for objective analysis of these effects as part of the governmental process[25]. (These build on top of longer-standing requirements such as those of the Administrative Procedures Act, and the more recent Government Performance and Results Act.) A series of pan-governmental emphases which included aspects of clarifying objectives, measuring results, and seeking to view the Public as "customers", such as Total Quality Management and "Reinventing Government," have been conducive to use of a risk management approach beyond its required applications.

Along with establishing a firm risk management approach, as explained in Section A.3, above, the FBSA requires the opportunity for a full range of non-federal involvement, from State to citizen, in federal boating safety decisions. This involvement is again characterized by a sampling of language directly from the Act:

"... the policy of Congress ... to improve boating safety and foster greater development, use, and enjoyment of all the waters of the United States by encouraging and assisting participation by the several States, the boating industry, and the boating public in development of more comprehensive boating safety programs ....uniformity of boating laws ... a higher degree of reciprocity and comity ... and closer cooperation between the Federal Government and the several States in developing, administering, and enforcing ... laws and regulations pertaining to boating safety." (Sec. 2)

and, further, as regards participation by the States:

"In order to encourage greater State participation and consistency in boating safety efforts, the Secretary may accept State boating safety programs...(and)...Federal financial assistance under this Act. ...the Model State boat Act as approved by the National Association of State Boating Law Administrators...Council of State Governments...to insure uniformity and promote comity among the several jurisdictions (in law enforcement, education, administration, reporting) ...liberally construed to permit acceptance where the general intent and purpose ...are met....receive funds .... insure the fullest cooperation between the State and Federal authorities in promoting boating safety by entering into agreements.... Federal Preemption...(but States not discouraged from more extensive or comprehensive action)....vessel numbered in State of principle use (with recognized validity in other States) .... (State) may require that the operator a numbered vessel hold a valid safety certificate .... uniform vessel casualty reporting.
and as regards other still participants:

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[25] For example, quoting from a description of proposed "Regulatory Improvement Act of 1998" (S981) by the Committee on Governmental Affairs: "S. 981 is a bipartisan effort to .... subject all "major rules" to rigorous economic and scientific analysis before being issued. By elevating the use of modern decision making tools such as cost-benefit analysis and risk assessment ....."

"In carrying out his responsibilities under this Act the Secretary may consult with State and local governments, public and private agencies, organizations and committees, private industry, and other persons having an interest in boating and boating safety....In establishing a need for formulating and prescribing regulations and standards...the Secretary shall .... consult with the Boating Safety Advisory Council ... to assure balanced representations, members shall be drawn equally from (1) State officials ... (2) boat and associated equipment manufacturers, and (3) boating organizations and members of the general public. ... shall consult with the Council on any other major boat safety matters related to this Act. .... (manufacturers to notify others of safety defects in boats ... able to self-certify reasonable and necessary non-compliance with regulations) .... funds...for national boating safety activities of national nonprofit-public service organizations.... delegate to any person, or private or public agency...functions respecting the examination, inspection, and testing...or for the development of data .... operators of a vessel ...shall render all practical and necessary assistance...shall not be held liable...(if) prudent .... reasonable diligence ....unless such person knows or reasonably should have know...."

These requirements can be viewed as limitations or as opportunities. In a well-functioning risk management setting, many of these relationships, empowered by a collegial focus on safety, would be viewed as highly desirable opportunities for review, development of support and coordination of implementation of resulting policies. The sum of the above is a process that accords every level an authority and input, in all stages, in the process of determining consequential government interventions in public life, and seems to meet the intent of the National Research Council's call for effective risk communication.[26]

The following quotation from Thomas Jefferson (in a letter to William C. Jarvis, 1820) seems relevant to stakeholder involvement at a fundamental level:

"I know of no safe depository of the ultimate powers of the society but the people themselves; and if we think them not enlightened enough to exercise their control with a wholesome discretion, the remedy is not to take it from them, but to inform their discretion by education."[27]

We will now shift attention from management processes to the content of the accident situations they are created to control, the subject of risk assessment.

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[26] National Research Council; Understanding Risk: Informing Decisions in a Democratic Society; 1996.

[27] John Bartlett; Familiar Quotations; Little-Brown 15th Edition (E. Beck, ed.); 1980; p. 389.

(Chapter II)
B. Preliminary Safety Analysis: An Inclusive View

1. *Considering the Whole Problem*

The whole process of boating *risk assessment* is done to help make decisions that improve boating safety. The process looks toward selecting the "best" things to do to decrease boating accident *frequency* and *severity* based on an improved understanding of the boating accident situation. The subjects of our interest extend to matters that are fixed before the accident takes place, for example:

- Did the person know how to use the boat in this environment?
- How effective was the life-saving equipment that was onboard?
- Were reliable weather forecasts available?

In the same way, our concern for the ultimate outcome of an accident extends beyond the accident event itself, for example:

- Did the boater try to swim to shore?
- Was she eventually rescued?
- Did the boy survive his injuries?

It is apparent that potential elements in the solutions to boating safety problems lie in decisions and events that take place both before and after (as well as during) the sequence of events we might choose to call "the accident." We will refer to these as the *Pre-accident, Accident and Post-accident Phases*. (We will also consider a more fundamental *Predisposing* situation.)

Through this *systematic* process, we are seeking to identify the contributing factors in different types of accidents in order to more fully understand their causes and identify possible solutions. A part of this discipline is an attempt to be *inclusive*, to identify and *deliberate*ly consider the importance of all relevant factors. To the extent that we fail to do so -- whether from a sense of urgency, bias for a particular type of solution, or lack of effort, skill or insight -- we risk accepting an inefficient solution, one with some combination of increased loss, wasted resources, excessive constraint and artificial means. (On the other hand, there is a balance to be struck between benefits of inclusiveness and the cost of detailed analysis. It is usually best to perform an analysis in stages, initially thinking broadly, deciding what seems important, then focusing on significant details, but always being willing to revisit the assumptions of the initial screening. The solution is *iterative*.)

In this initial investigation of boating accident factors, we have chosen a strategy for obtaining an inclusive view that involves stepping back and considering the broader category[28] of

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[28] Something could also be learned by approaching boating as a category of "recreation."

Transportation Accidents, in terms of the three phases we mentioned -- before, during, after -- with the "before" divided into a more general predisposing phase, and a more immediate pre-accident phase. This will produce an inclusive structure within which to consider boating accidents in greater depth.

2. *A General Accident Structure*

The rather lengthy table of Figure II.B.1, following, was developed to indicate the inherent structure of transportation accidents, including boating, but broader. (This figure is repeated in Appendix "A" in an easier to read, extended format.) There are pared columns. The column on the left lists and illustrates steps or events in the evolution of an accident involving a person or persons upon whom we are focused. At its most basic, this is a predisposing/pre-accident/accident/post-accident sequence. (Some steps/events may have a "null" expression in a particular accident sequence, i.e., they may not be involved.) The column on the right lists possible types of influences (non-intentional) or interventions (intentional) that proceed from the accident environment and influence the next event in the accident sequence. All of these are capable of a sequential graphical presentation, one step influencing the next. (Human errors, the other major area of this report fits into this situation as determinative qualities of, or decisions made by, people involved in the accident evolution.)

This is a complex presentation when viewed as a whole. However, it is easily understood in its individual components and in its general flow, as discussed below.

Figure II.B.1: GENERAL ACCIDENT STRUCTURE

FOCAL SITUATION	EXTERIOR INFLUENCES AND INTERVENTIONS
PRIOR STATE	
PRE-DISPOSING ELEMENTS	(Basic Options within a Larger Setting)
	REGIONAL SETTING Social/Legal Physical/Material State of Available Knowledge
PERSONAL STATE Personal History Intelligence Knowledge Values Attitudes Skills/Abilities Health Wealth Relationships Others	
	MATERIAL ATTRIBUTES Boat Design Construction Material Workmanship Prior Use Condition Outfitting Other
PRE-OPERATIONAL	(Choice of Specific Operating Parameters)
PLANNING Purpose Awareness People involved Location Timing Expected conditions Equipment Components Arrangements	***Continued at right***

	INTENT (Actionable embodiment of personal characteristics and planning)
SETUP Boat Outfitting Personal gear Provisions Information Communication	
	ENVIRONMENT ATTRIBUTES Physical: -Weather -Water -Boundaries -Obstructions -Designed transit layout - Road/Track Other Actors: - Type - Number - Location/Distribution Other Characteristics Social/Legal Assessment
INITIAL OPERATION	(Begin Operation; Pre-hazard Onset)
INITIATION Movement to the Operating Environment Perception of Environment Assessment Final Preparations	
	INITIAL INTERACTION Environment Material Personal Social Types and Rates of Change
CONDUCT Acclimate to Steady-state Operation Establish Characteristics of Routine Response	***Continued next page***

HAZARD DEVELOPMENT	(Perceptible, Actionable Onset of Hazard)
	PARTICULAR HAZARD INTRODUCED Characteristics: - type - extent - timing - uncertainty
PERCEIVE HAZARD Objectivity Comprehension Readiness to react: - knowledge - skill/ability - psychological - material	
	HAZARD SITUATION DEVELOPS Alternative paths Likelihood
EVALUATE HAZARD Continue to Observe Identify Values at Risk Likelihood Consequences Intensity	
	HAZARD SITUATION DEVELOPS
EVALUATE RESPONSE Continue to Observe Identify Alternatives Consider Feasibility Seek Advice Experiment Estimate Success Rate Choose Course of Action	
	HAZARD SITUATION DEVELOPS
ACT ON HAZARD Do not act Act to avoid Act to mitigate	
	HAZARD REALIZED (Yes/No) ***Continued at right***

ACCIDENT	(Accident Event Onset)
ACCIDENT SEQUENCE Initial event Automatic Consequences Immediate Actions Affecting Outcome Sequence of Subsequent Events Call for Help?	
	EXTERNAL INTERACTION Continued Environmental Stress Continued Inter-object/personal Stress Changes in Situation Boundaries
IMMEDIATE ACCIDENT OUTCOME Life Health Material Wealth Common-wealth Environmental Change	
POST-ACCIDENT	(Begin Potential Recovery)
POST-ACCIDENT ACTION Amelioration Self-rescue/Recovery	
	POST-ACCIDENT INTERVENTION Search Rescue Assistance Renewal
PERSONAL CHANGES Life Health Wealth Knowledge Skills/Abilities	
	EXTERIOR MATERIAL CHANGES Commonwealth ENVIRONMENTAL CHANGES Alter: enhance/degrade SOCIETAL CHANGES Other people/groups involved Knowledge Intentions/Outlooks Organizations Law Culture
FINAL STATE	(Changes Absorbed)

3. *A Boating Accident Flow Model*

When viewed in outline, the General Accident Structure, Figure II.B.1, preceding, is an easily understandable flow of events before, during and after an accident, leading from a certain "prior" state (influenced by what we are calling predisposing factors), through the buildup of an accident, its completion, and consequences, to a "final" state. This is presented in a simplified general accident *flow diagram* in Figure II.B.2, below.

It will be recognized that there is also an intermediate level of detail which includes, for example, the elements of Planning, Intent, Setup and Environmental Attributes in the Pre-Operational Phase of the list comprising the General Accident Structure. Each of these contains a list of factors that may apply at that level. This flow and its content represent the general progression of an accident. Boating accidents can be viewed in terms of this model. The model helps organize an analytic approach and serves as a reference that brings to mind elements of the problem that might otherwise be overlooked. Details can be included or not as (explicitly) determined for the problem at hand. The flow model of Figure II.B.2 will serve as the basic structure for considering individual boating accident types in the sections that follow. (Essentially the same model is printed across the tops of the diagrams used to develop the components of boating accident type in the sections that follow.)

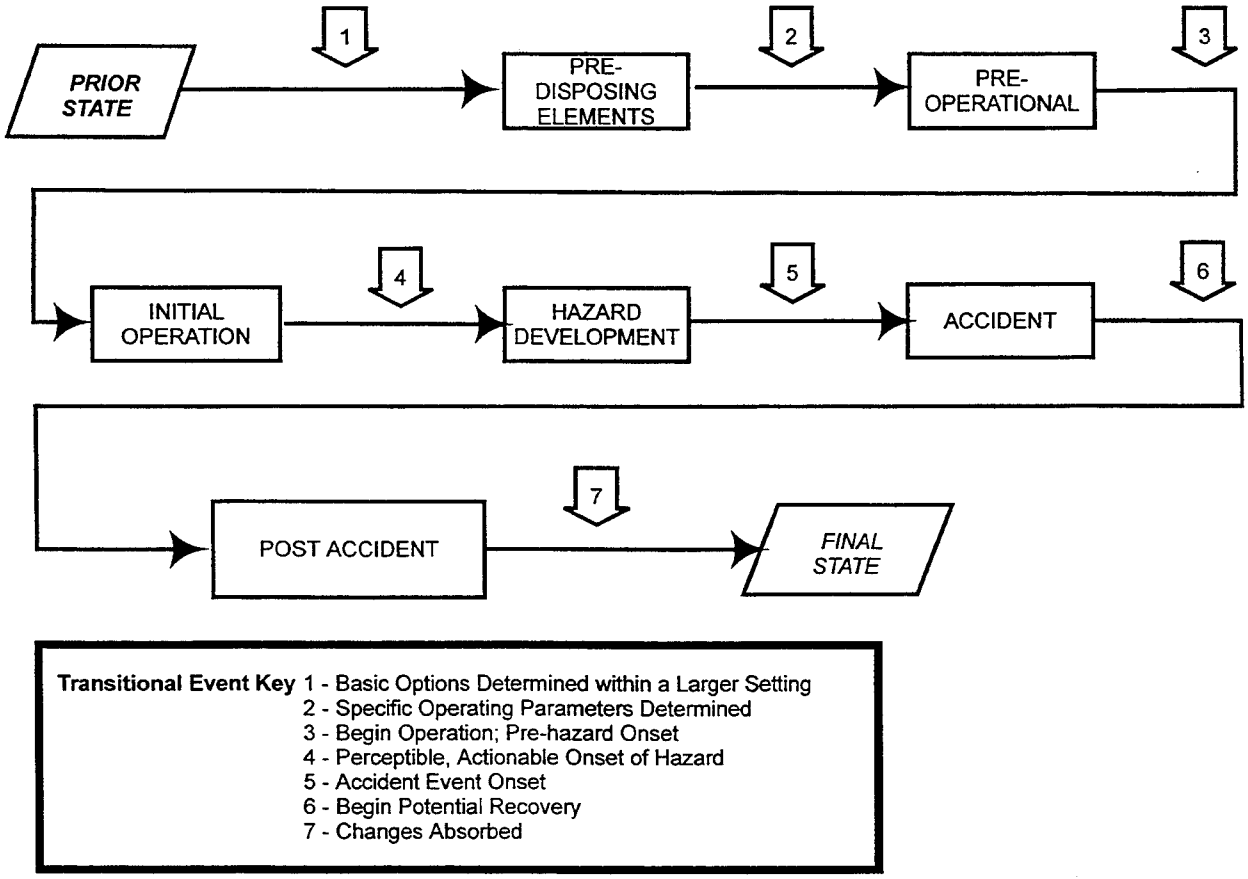

Figure II.B.2: GENERAL ACCIDENT FLOW DIAGRAM

(Chapter II)
C. Boating Accident Hazard Characterization and Qualitative Analysis

1. *The Recreational Boating Safety Database*

Anything that can go wrong does go wrong at some time on boats.[29] Boating accidents subject people to drowning, hypothermia, burns, and all manner of impact and cutting injuries. Federal law requires the reporting of certain categories of boating accidents to the Coast Guard, generally through the States. One result is a highly credible record of annual numbers of *fatalities* associated with boating in the U.S., extending back several decades.[30] Looking at the period from 1961 to 1996, annual reported fatalities have ranged from a high of 1754 to a low of 709. There has been a general trend downward in the number of fatalities over the years. The annual number has been consistently below 1000 for the last ten years for which data are available. For most of the last twenty years there has been a decrease in a (proxy or surrogate) annual boating "fatality rate" computed as the ratio of the total number of fatalities to the estimated total number of boats in the U.S. that year.[31] This fatality rate showed a steady decline through the 1980's and most of the mid-1990's, presumably in response to measures taken following enactment of the FBSA. Boating accident report (BAR) case data is compiled nationally by the Coast Guard from data provided by the States. Since 1996, much of this has been provided as part of an electronic Boating Accident Report Database (BARD) which facilitates computer analysis of the data. (The BARD is discussed in detail in Chapter III in connection with human-error accident sources.)

This *database* is an important boating accident information resource. It is structured to allow recordation of the basic facts of individual reported accidents, together with a degree of detail in areas that have been of historic interest. These include coded information on accident types,

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[29] This will be evident in the human-errors analysis of about 1000 cases from the 1997 boating accident database which is presented in Chapter III and summarized in Appendix D.

[30] While federal law requires reports of boating injuries and property damage exceeding certain thresholds, there is not comparably credible data for these accidents due to low rates and non-random reporting. At present, such reports are primarily useful as sources of anecdotal information.

[31] This is not an ideal measure, but is often seen as the best indicator, because of the difficulty of estimating boat use directly. (The annual estimate of boat numbers depends on infrequent surveys to establish baseline ratios that are used in this computation. Further, there is little reason to think average boat use remains constant from one boat type to another or from year to year.) At best, this measure *implies* a relationship between exposure to the hazards of boating and resultant fatalities. A preferable measure would be in terms of fatalities per (time) unit of exposure, as used in most industrial accident studies and DOT modal statistical summaries, and comparable to the NSC, ANSI and USAS standards for accident frequency rate (or incidence rate) reporting of industrial accidents. The Coast Guard's formal presentation was changed to show "fatalities per 100,000 *numbered* boats" in 1996, the number of legally registered boats being more consistently and better known.

apparent causes and severity, as well as characteristics of the boat, boaters and accident environments. (Some reports include a narrative summary of the accident that provide information that supplements the coded accident data. Chapter III discusses our review of a sampling of the 1997 report narratives for human-error accident causes.) These data are consolidated, tabulated and compiled annually.

All of the coded information on the boating accident reports (BAR's)[32] is accessible for analysis in the annual BARD compilation. In this form, they provide a significant source of information on accident trends and input into safety analysis. We will use their categories in our analyses to allow connection to the database. Data is available for the boat types as follows:

- open motorboats	- cabin motorboats	- auxiliary sailboats	- sail (only)
- rowboats	- canoes/kayaks	- personal watercraft	- pontoon boats
- houseboats	- others (specify).		

The sources of accidents in a number of these categories were assessed in several studies, especially the Wyle studies cited earlier. Most of these studies provided systematic breakdowns of accident causes for the types of boats they addressed. (They ask, for example: "How do canoe accidents develop.") These were generally presented as diagrams of the logical connections among alternative events in the casual sequence of an accident. (The diagrams take the form of a branching trees, thus "*hazard trees*," or similar nomenclature.) In their later development, these are accompanied by statistical indications of the likelihood of different accident characteristics and outcomes, based on the annual data compilations. (Figure II.A.1, the Wyle diagram of cumulative collision causes presented earlier, is an example.) These generally suffice as an indication of the considerable benefit of this approach, forcing the analyst to discern the connections among the conditions leading to accidents in a type of boat, and applying (limited available) statistical information to quantify the importance of these causes as gross indicators of where *intervention* is desirable to improve safety.

[32] A copy of the 9/95 revision of the BAR showing the reported data fields is provided for reference in Appendix B.

2. *Characterization of Hazards by Accident Type*

We will move in a somewhat different direction, growing out of our previous discussion of a general transportation accident model and focusing on types of accidents, rather than types of boats. Coded BAR *accident types* include the following, presented *in order of 1996 boating fatality* involvement[33]:

- capsizing
- falls overboard
- other/unknown
- collision with another vessel
- swamping and flooding
- collision with fixed object
- sinking
- collision with floating object
- struck by boat
- grounding
- struck by motor/propeller
- falls within boat
- skier mishap
- other fire or explosion
- fire/ explosion, fuel
- struck submerged object.

Analysis in these categories is supported by decades of recorded data. Some of the categories account for few fatalities, but are necessary for a logically inclusive breakdown. Many boating deaths occur beyond observation and the "other/unknown" category is typically within the range of 5-15%. To allow inclusive treatment without excessive redundancy, we have combined similar accident types into the six categories, as follows (listed *in order of combined percent of 1996 fatalities*):

- Capsizing/Swamping/Flooding/Sinking
- Falls (Overboard and Within Boat)
- Collisions (all)/Grounding (inc. Struck Submerged Object)
- Unknown/Other
- Struck by Boat or Propeller/Fallen Skier
- Fire/Explosion.

The first three categories are by far the dominant fatal accident sources,[34] 84% in 1996.

In the sections that follow, we will amplify the general boating accident flow model of Figure II.B.2 to incorporate content specific to all except two of these accident categories. We are not able to deal with the "*Unknown/Other*" accident type coherently, because it combines disparate and unidentified accident types. We also choose to leave the "*Struck by Boat or Propeller/Fallen Skier*" category for future investigation. It is a different class of problem in which the person is subject to harm by the boat as an object in his "environment." The preliminary analysis of the remaining four unambiguous accident categories which follows is worthwhile because they typically account for 80 - 90 percent of annual boating fatalities.

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[33] 1996 boating fatality data, here and following are from the USCG publication Boating Statistics - 1996.

[34] An analysis could also be done by cause of death. Drowning is the leading cause of death: 71 % in 1996.

We will develop the content of each of the phases in the general accident flow model of Figure II.B.2 for each of these four accident categories. In each case, we will begin by focusing on what seem to be the primary *determinants of the events in the "Accident Phase"* and build up to those as we consider the preceding phases. For example, in the first set of scenarios related to *Capsizing, etc.*, we will focus on different ways in which water can enter the boat in a catastrophic way: either by a mismatch in the motion of the boat relative to the water in which it is floating, or by a structural failure that allows water to enter the boat. In the second set, *Falls, etc.*, we will focus on the interrelation between the boater and some (moving or stationary) object that gives him the misdirected momentum that results in his harm. The following table indicates our choices of first- and second-order accident determinants for analyzing these four accident categories:

Accident Type	Primary Accident Determinants	Secondary Accident Determinants
Capsizing/Swamping/ Flooding/Sinking	boat motion with respect to (w/r/t) the water; structural failure.	boat; boater; environment.
Falls (Overboard and within Boat)	boat motion; tripping; being struck or pushed.	boat; boater; environment.
Collisions (all)/ Groundings (inc. Struck Submerged Object)	own vessel motion w/r/t another's; own vessel motion w/r/t elements of its environment. (Objects, land)	boat; boater; environment.
Fire/Explosion (both)	fuel; oxidizer; ignition source.	boat; boater; environment.

Figure II.C.1: SELECTED BOATING ACCIDENT DETERMINANTS

In each case, the Accident Phase determinants can be traced back, categorically, to factors existing in the Hazard Development Phase, the Pre-accident Phase and the Predisposing situation. These will be considered in a consistent Boat/Boater/Environment format representing the entire *system* we are viewing and its potentials for interaction with outside influences. In doing so, a catalogue of attributes will be developed which, in their interaction, describe the factors that contribute to the accident. Once it is understood how these factors relate to each other, changes in some can be investigated and compared as possible means of preventing the accident and subjects of more detailed analysis. The four composite accident types are discussed below.

2. a. *Capsizing/Swamping/Flooding/Sinking*

This category combines accidents due to Capsizing, Swamping, Flooding and Sinking, as indicated in the database. This type of accident occurs in one of two ways, either:

a. the *motion* of the boat, relative to the water is such that water enters the boat; or
b. there is a *structural failure* such that water enters the boat.

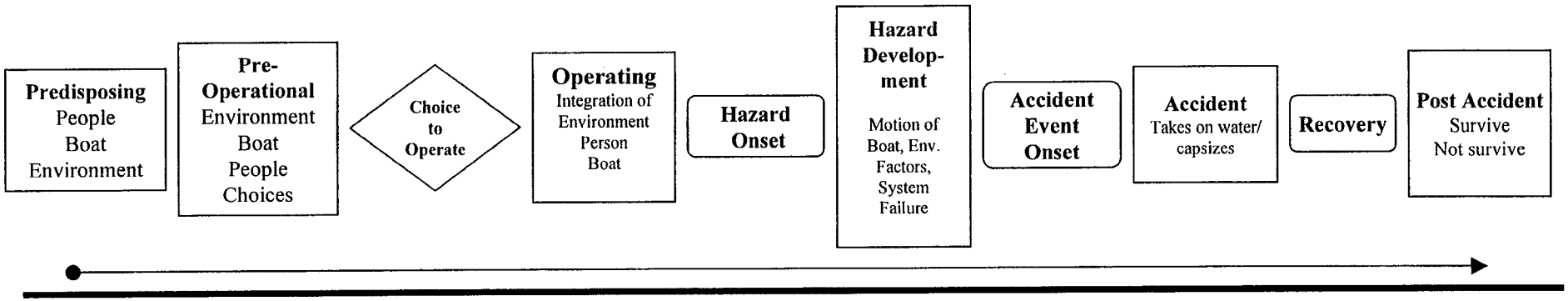
Please refer to Figure II.C.2, following. The Hazard Development Phase is seen to focus on these two possibilities.

Continuing to refer to Figure II.C.2, it will be seen that a consistent boat/boater/environment breakdown has been maintained in each of the phases leading up to the accident, allowing tracking of influences from phase to phase. (We concentrate on the effects of the accident on the person, as our primary concern, during and after the accident.) In the (pre-accident) Hazard Development Phase, we note "*people*" causes related to the boater's control of the boat, his skill, and his choices, in case (a), capsizing, swamping, etc. due to the relative motion between the boat and the water. In case (b), structural failure, we see *people* causes related to boat maintenance, choices of changes to the boat that could cause structural failure, and skill in making modifications. (In both cases, these "*people*" causes had to do with lack of skill, knowledge or wisdom in using or maintaining the boat. If we look back (in Figure II.C.2-A) to the Pre-operational Phase, we note an expanded treatment of the antecedents to these failures. If we look back farther to the Predisposing conditions, we get yet more basic, in terms of why the *people* exhibit the failings they do: lack of training, experience, attitude and motivation, etc. There is, thus, a clear path through these early stages to the "*people*" contributions to the accident.

We can track *"boat"* and *"environmental"* conditions similarly. In the case of the boat, we can track the determinants of both its (a) *motion* and (b) *structural failures* from Predisposing conditions such as design knowledge and availability of suitable materials and components, through a Pre-operational concern for how these are set-up and maintained, to the Hazard Development Phase in which particular operating conditions produce either an incipient mismatch in boat and water motion or a structural failure which will eventually result in capsizing, swamping, flooding and/or sinking.

In the case of *environmental* determinants, one can track Predisposing conditions of the *physical environment* like local geography in the operating area, or of what we are calling the *social environment*, such as location of channels and breakwaters, or of water usage customs or the level of lawlessness in local society through intervening Pre-operational characteristics -- like sea and weather conditions, availability of community services, and others in Figure II.C.2 -- to their ultimate affect on (a) boat motion or (b) structural failure.

Figure II.C.2: CAPSIZING/SWAMPING/FLOODING/SINKING ACCIDENT FACTORS



Factors in play at different stages

Predisposing

People
Training
Education
Experience
Attitude

Boat
Design
Design stability
Configuration
Construction
Systems
Equippage

Environment
State of Knowledge
Customs/Traditions
Culture
History

Pre-Operational

See Fig. II.C.2-A

People
Skills
Knowledge
Preparation
Attitudes

Boat
Condition
Maintenance
Loading/Stowing
Outfitting

Environment
Weather & Sea Conditions
Government Services

Operating

People

Boat

Environment

Hazard Development

See Fig. II.C.2-A

Motion
- **People**
- **Boat**
- **Environment**

Structural/system failure
- **People**
- **Boat**
- **Environment**

Combination of Motion & Structural factors

Accident

Characterize vessel's time/sequence of events, indicating progressive status of

People

Boat

Environment

Post-Accident

Survive
Rescued by others
-own boat
-others

Self-rescued
-damage control
-float /swim /walk ashore

Not survive

Seconday Hazard? Injured?

Notes: 1. Within accident stages, these attributes are identified that may only apply to this (Capsizing/Flooding) scenario.
2. Focus is on determinants of person's safety rather than the boat in this scenario.
3. Attributes may ovrlap in content to assure that they include all forseen possibilities.
4. May transition to or from other scenarios such as "Collision/Grounding" or "Overboard."

It will be noted that in the Accident Phase, our focus narrows to the affects of the accident on the people involved, even though what happens to the boat (or environment) may have an intervening affect, such as the boat sinking, leaving the person in the water. Our principal concern in the Post-Accident phase remains for the condition of the boater, concern for the boat or its environment being viewed as instrumental in that regard, not as an end in itself.

Please refer to the schematic at the top of Figure II.C.2 to review how this subject is developed. Each of the phases preceding the accident is assessed for information that points forward to illustrate the determinant factors for the accident type, just mentioned, while maintaining a distinction among boat, boater and environmental causes. This organization facilitates construction of a flow diagram of the factors or events that contribute to the accident for use in analysis as described later. The comparability with the human-error descriptions developed in Chapter III is also noted.

Pre-Operational Phase Breakdown

People:	**Boat**	**Environment:**
Skills	-Condition & Maintenance	Sea and Weather Conditions
Preparation	of Vessel and Systems	External factors
Knowledge of Safe Practices	Maintenance	Underway/Anchor/Dockside
Knowledge of boat	Condition	On-board activities
Concern for self	Maintenance	Availability of Assistance
Concern for others	Loading/Stowing	Location
Risk tolerance	Bilge water	Other users
Physical/mental State	CG-GM	Govt. Services -
	Pumps	- Buoyage/ATON
	Safety/rescue equipment	- Charts

Hazard Development Phase Breakdown

People:	**Boat**	**Environment:**
Motion	***Motion***	***Motion***
Actions	Fixed Condition	Wind
Awareness	Temporary Condition	Waves
Analysis	Transient Condition	Bottom
Choices & Decisions		Current
Control		External Factors
Skill		
Structural/system failure	***Structural/system failure***	***Structural/system failure***
Maintenance	Design	Waves & wind
Alteration	Construction	Obstructions
Operational action	Maintenance	Ground
	Motion	Other Vessel / object

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Figure II.C.2-A: BREAKDOWN OF TWO PHASES OF CAPSIZING/SWAMPING/FLOODING/SINKING ACCIDENT FACTORS

2.b. *Falls (Overboard and Within Boat)*

This group of scenarios combines the two indicated BARD accident data categories, Falls Overboard and Falls Within Boat. We will focus on causes of falling, of a person's loosing control of his motion. We see three classes of causes:

a. the person trips,
b. the person is directly acted upon by the motion of the boat, or,
c. the person is hit by some object in motion.[35]

All can lead to changes in the person's momentum, resulting in an accident. The person can be injured (by impact, cutting, heat, etc.) or fall overboard, where he is subject to the hazards of being in the water. Figure II.C.3 identifies causes for each class in terms of their source in the person, the boat or their environment. These factors are particular to the case: the person is inattentive or impaired, the deck is slippery, gear is unsecured, a wake causes boat motion, etc. We can then look back into the preceding phases to consider how they might come about. In doing so, we develop a catalogue of ideas which describes the factors that contribute to the accident. These can be reviewed, screened and investigated in greater detail to determine major causes and possibilities for preventing the accident. (This process will also be discussed in Chapter IV, under the subjects of RBS policy-analysis and selection and evaluation of alternatives.) In Section II.C.3, following, we will extend the analysis of the *Falls* category beyond identifying contributing factors to organizing them in simple flow/logic and decision diagrams, the latter identifying interventions which would prevent the accident.

2.c. *Collision/Grounding*

In this case, we focus on the accident phase determinant of collisions and groundings. This is relative motion between one's own vessel and another, or some other element of the "own vessel's" environment, fixed or moving, natural or not. Again, contributing factors can be traced from phase to phase in boat/boater/environment categories. Figure II.C.4 develops the Collision and Grounding scenario breakdown. Pre-operational factors are expanded in Figure II.C.4-A.

2.d. *Fires/Explosion*

Here, Accident Phase attention is focused on the three determinants of any fire or explosion: (a) fuel, (b) oxidizer and (c) ignition source. The process of connecting determining factors, phase to phase, remains the same. Please see Figure II.C.5.

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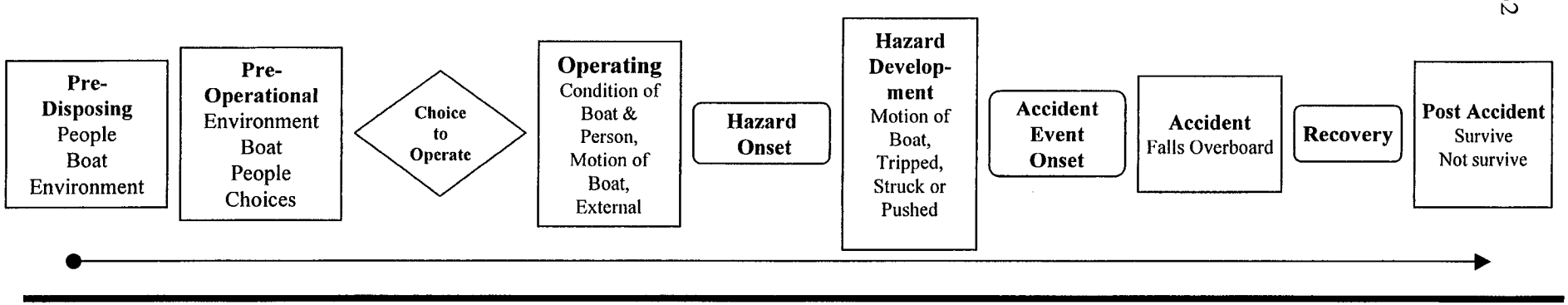
[35] We have ignored a forth possible cause, that the person is pushed, intentionally, by another person. This case develops differently from the others in considering the decision processes of the one doing the pushing.

Figure II.C.3: FALLS (OVERBOARD and WITHIN BOAT) ACCIDENT FACTORS



Factors in play at different stages

Predisposing

People
Training
Education
Experience
Physical Ability
Mental Ability
Attitudes

Boat
Design
Configuration
Construction
Equippage

Environment
Regulation
Waterway Types
Social
Support Systems
NWS
Aids to Nav.

Pre-Operational

People
Local Knowledge
Knowledge of Boat
Knowledge of Environment
Psycho-physio condition
Preparation

Boat
Readiness
Maintenance
Outfitting

Environment
Sea & Weather Conditions
Availability of Services

Operating

People

Boat

Environment

Hazard Development

See Fig. II.C.3-A

Motion

- People

- Boat

- Environment

Tripping

- People

- Boat

- Environment

Struck or Pushed

- People

- Boat

- Environment

Accident

Characterize time/sequence of events indicating progressive status of:

People
Wear PFD
Conscious
Thermal
Signal
Swim
Stay
Impact
Injuries
When/where

Boat

Environment
Visibility
Day/night
Water Temp.
Air Temp.

Post-Accident

Survive
Rescued by others
-own boat
-outside
-stay with boat
-not stay with boat

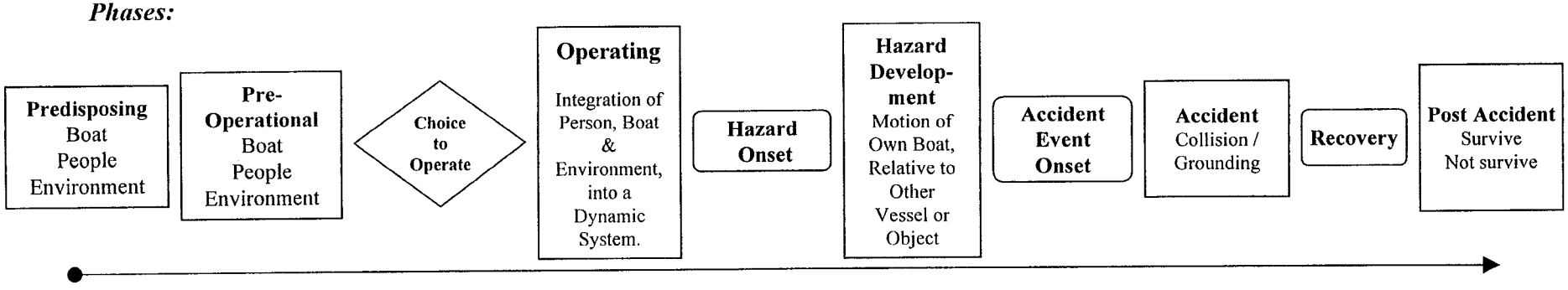
Self-rescued
-float /swim /walk
-re-board

Seconday Hazard?
Injured?

Not survive

Notes:
1. Attributes are identified that may only apply to this (falls overboard) scenario.
2. Focus is on determinants of person's safety rather than the boat in this scenario.
3. Attributes may overlap in content to assure that they include all possibilities.
4. May transition to or from other scenarios such as Collision or Capsizing.

Figure II.C.4: COLLISION / GROUNDING ACCIDENT FACTORS



Factors in play at different stages

Predisposing

People
Education
Training
Experience
Attitudes
Behavioral Factors

Boat
Design
Handling
Draft
Configuration

Environment
State of Knowledge
Customs/Traditions
Culture
History
Physical Properties

Pre-Operational

See Fig. II.C.4-A

People
Skills & Knowledge
Physical/Psycho.
Condition
Personal
Attitude/Outlook
Personal Outfitting

Boat
Structure
Equipment
Information

Environment
Physical Environment
Other Waterway Users
Social Environment

Operating

People

Boat

Environment

Hazard Development

Own Motion

People
Awareness
Perception of Other Vessel or Object's Position, Motion and Intent
Perception of own geographic position
Analysis
Decisions

Boat
Its motion is the product of:
Boat Characteristics
Its Environment
People.

Environment:
Same factors as Pre-Operational Phase Breakdown
Time

Other's Motion
{**Note:** Reflects the same determinants as for own vessel.}

Accident

Own Vessel

Characterize own vessel's time/sequence of events, indicating progressive status of :
People
Injured
Killed
Ejected
Entrapped
Impaled
No injury

Boat

Environment

Post-Accident

Survive
Rescued by:
own boat
others.
Self-rescued:
re-board own boat
stay with boat?
swim/float/walk ashore

Secondary Hazard?
Injured?

Not survive

Notes: 1. Attributes are identified that may only apply to this (collision/grounding) scenario.
2. Our specific focus is on determinants of the boat operator's safety, rather than on the boat's.
3. Attributes may overlap in content to assure that they include all foreseen possibilities.
4. May transition to other scenarios such as "Overboard" or "Capsizing/Flooding".

Pre-Operational Phase Breakdown

People:	Boat	Environment:
Skills & Knowledge:	***Structure:***	***Physical Environment:***
Rules of the Road	Stability	Channel Configuration
Local Knowledge	Seaworthiness	Depth of Water
Local Custom	Suitability	Width of Nav. Area
Use/Control of Boat	Maneuverability	Length of Nav. Area
Human Behavior	Control	Land
Navigation & Piloting	Human Factors	Structures
	Passive Floatation	Obstructions
Physical/Psycho. Condition:	Visibility	Floating Objects/Debris
General Health/Illness	Nav. Lights	Weather
Physical Limitations	Maintenance	Seas
Vision		Chemical Characteristics
Hearing	***Equipment:***	Biological Characteristics
Ability to Control Vessel	Propulsion	Bottom Characteristics
Reactions	Steering	Changes to Physical Env.
Drugs & Alcohol	Compass	
Seasickness	Binoculars	***Other Waterway Users:***
Mental Impairment	Radar	Colliding Vessel
- Permanent	Radio	- (Duplicate Range of
- Temporary	Other communication	Own Characteristics.)
	Electronic Navigation. Systems.	Other Vessels
Personal Attitude/Outlook:	Depth Finder	- Other Users
Risk Tolerance	Radar Reflector	- Conflicting Users
Concern for Self	Anchor System	- Assisting Users
Concern for Others	Safety Equipment	
Personality Descriptors	Flares	***Social Environment:***
Character	Lifeboat/liferaft	Traffic Flow
	MOB Recover	On-Shore Activity
Personal Outfitting:	Fire Extinguisher	Water Access Provisions
Clothing	Horn	Other Vessels
Corrective Optics, Hearing	Strobe/light	Government Services:
Prosthetics	Maintenance	- Waterway Marking
PFD		- Waterway Dredging
Thermal Protection	***Information:***	- Weather Forecasting
Personal Safety Equipment	Charts	- Navigation Systems
	Coast Pilot	- Laws & Regulations
	Rules of Road	- Law Enforcement
	Tides/Currents	- Educational Systems
	Weather	- Search and Rescue
	LNM -Changes	- Charting
	Local Info.	Commercial Support
	Internet	Market-place Influences
	Service Info.	Information Systems
		State of Knowledge
		Customs/Traditions
		Culture
		History

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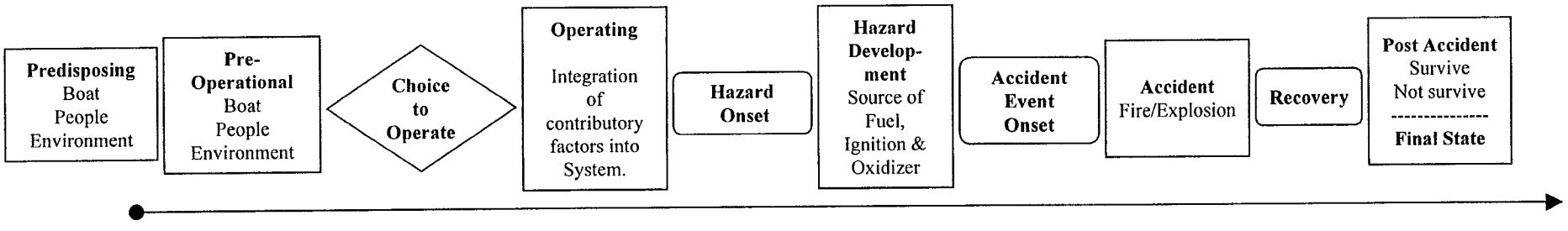
Figure II..C.4-A: BREAKDOWN OF PRE-OPERATIONAL PHASE OF COLLISION/GROUNDING ACCIDENT FACTORS

Figure II.C.5: FIRE and EXPLOSION ACCIDENT FACTORS

Phases:



Factors in play at different stages

Predisposing

People
Training
Experience
Education
Attitude

Boat
Fuel Characteristics
- Combustibility
- Volatility
- Volume & Storage

Electrical System
Vessel Configuration, Construction & Matl.
Ground System
Extinguishing systems

Environment
Physical Environment
Physical Properties
Social Environment
- Regulations
- Standards

Fire/Rescue Capabilities

Pre-Operational

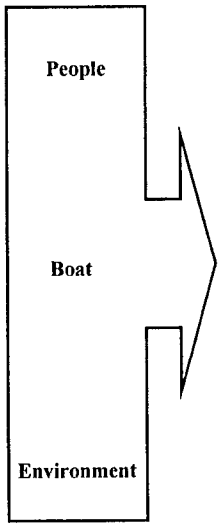
See Fig. II.C.5-A

People
Skills & Knowledge
Preparation
Physical/mental State

Boat
Fuel Sources
Ignition sources
Presence of Oxidizer
Presence of Explosive
Maintenance

Environment
Physical Environment
External factors

Operating



Hazard Development

See Fig. II.C.5-A

People
Awareness
Analysis
Decisions

Boat
Fire
- Fuel
- Ignition Sources
- Oxygen Source

Explosion

Environment
Other Vessel
Pier
Oil on water
Embers
Fireworks
Lightning
Gun fire
Arson

Accident

Characterize time sequence of events indicating progressive status of :

People
Burned
Impacted
Blown Apart
Smoke
Other
-Poisoning
-Electrocution
Rescue gone wrong
CO2 Suffocation
Halon Poisoning

Boat
Loss of Buoyancy
Afire
Other damage

Environment
Wind, weather & Sea conditions

Post Accident

Damage Control, First Aid & Rescue

People
- **Survive**
  Extinguish Fire
  Not Extinguish Fire

Rescued by:
- own boat
- others.

Self-rescued:
- re-board own boat
- stay with boat?
- swim/float/walk ashore
- **Not survive**

Boat
Extinguish Fire
- Own boat
- Outside assistance

Not Extinguish Fire
- Abandon Ship
- Perish

Lost
Damaged
No Problem

Environment
Pollution
- water
- air

Notes:
1. Attributes are identified that may only apply to this (fire/explosion) scenario.
2. Our specific focus is on determinants of the boat operator's safety, rather than on the boat's.
3. Attributes may overlap in content to assure that they include all foreseen possibilities.
4. Fuel refers to any flammable materials present including vessel, fuel, cargo, etc.
5. May transition to other scenario such as "Overboard" or "Capsizing/Flooding"

Pre-Operational Phase Breakdown

People:	Boat	Environment:
Knowledge of Boat Knowledge of Safe Practices Preparation Skills Physical/mental State	Fuel Sources -Fuel systems -Fuel stowage -Equippage -Condition & Maintenance of Vessel and Systems - Debris - Condition of Ground Ignition sources -Bilge -Electrical -Static -Flame -Lightning -Smoking -Hot surface Presence of Explosive mixture Stowage Stowage of Flammables Maintenance Condition of -Fuel/electrical systems -Backfire Flame Arrestors	Sea and Weather Conditions External factors Underway/Anchor/Dockside Pier Fueling Layout Underway Shoreside activities On-board activities Fire/Rescue/Medical/Law Enforcement Availability

Hazard Development Phase Breakdown

People:	Boat	Environment:
Awareness Analysis Decisions	***Fire*** Fuel - Liquid fuel - Compressed gas - Component materials - Cargo Ignition Sources - Spark Static - Electrical system - Flame - Heat - Spontaneous Combustion Oxidizer - Air - Derived ***Explosion*** - Gasoline or Propane vapors - Explosives on board	Other Vessel Pier Oil on water Embers Fireworks Lightning Gun fire Arson

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Figure 2.C.5-A: BREAKDOWN of TWO PHASES of FIRE and EXPLOSION ACCIDENT FACTORS

3. ***Further Qualitative Hazard Analysis***

3.a *Methods*

The diagrams referred to above identify factors potentially affecting the four composite categories of boating accidents. Many of these factors are related to others as causes or attributes of accidents. Useful indications of these relationships can be established in a number of ways, among them, the following:

- tables (or check-lists) of accident characteristics (as in the foregoing.)
- accident scenerios, narratives, case studies and investigations.
- influence diagrams (depecting qualitative dependency or influence of one quality or event involved in the accident on others. This is depicted graphically as nodes, representing individual factors, joined by arrows showing the direction of influence of one quantity on another, forming a web of relationships. The technique is useful for beginning to organize an understanding of the dependencies in a problem. A number of computer programs allow simple construction of influence diagrams, as indicated in Section V.A.)
- various types of network or flow diagrams (producing a tighter structure of the logical connection of events in an accident, forming the basis for organizing closer attention and analysis. One more is illustrated below.)
- direct statistical comparisons (as, for example, the comparisons found in the USCG Boating Statistics publication, e.g., "N% of fatal boating accidents occur on weekends." Also, see the boating human errors comparisons of Table 2 of Chapter III.)
- other graphical representations (as, for example, plots of the variation of one factor, or component of the database, as a function of another.)
- expert opinion and group ranking processes.
- varities of semi-quantified techniques (blending into detailed, quantitative analysis. Examples include approximations where factors are scored as having, for example, a High, Medium or Low probability of occupance, or impact rated on a scale of 1 to 10, which can serve to screen them to identify candidates for more detailed analysis[36]. Sets of factors can be evaluated against one another in matrix form indicating trends in two related variables. This technique can be extended, mathematically, to higher dimensions. Relative rankings of the importance of multiple factors in a complex problem can be developed by weighting their relative importance using a scoring matrix, the basis of a technique of multi-attribute utility analysis.[37])

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[36] U.S. Coast Guard R&D Center (based on work performed by JBF Associates, Inc.); Integrated Risk Assessment (IRA) Manual; 1998. (Sections 2 and 3 present consice descriptions of a number of techniques.)

[37] Mandex, Inc. And Decision Science Consortium (in work performed for USCG Office of Research and Development); Recreational Boating Safety: Analysis for Programmatic Decisions; Chapter 3. Also, note Section IV.B.)

Hazard analysis is seldom an end in itself. Whatever the process, it should be determined and directed to serve the information and decision needs at hand. Qualitative methods generally serve to organize an understanding of the factors that enter into a situation and/or help to identify the more significant -- or screen out the less significant -- for analysis in greater depth. A simple example follows.

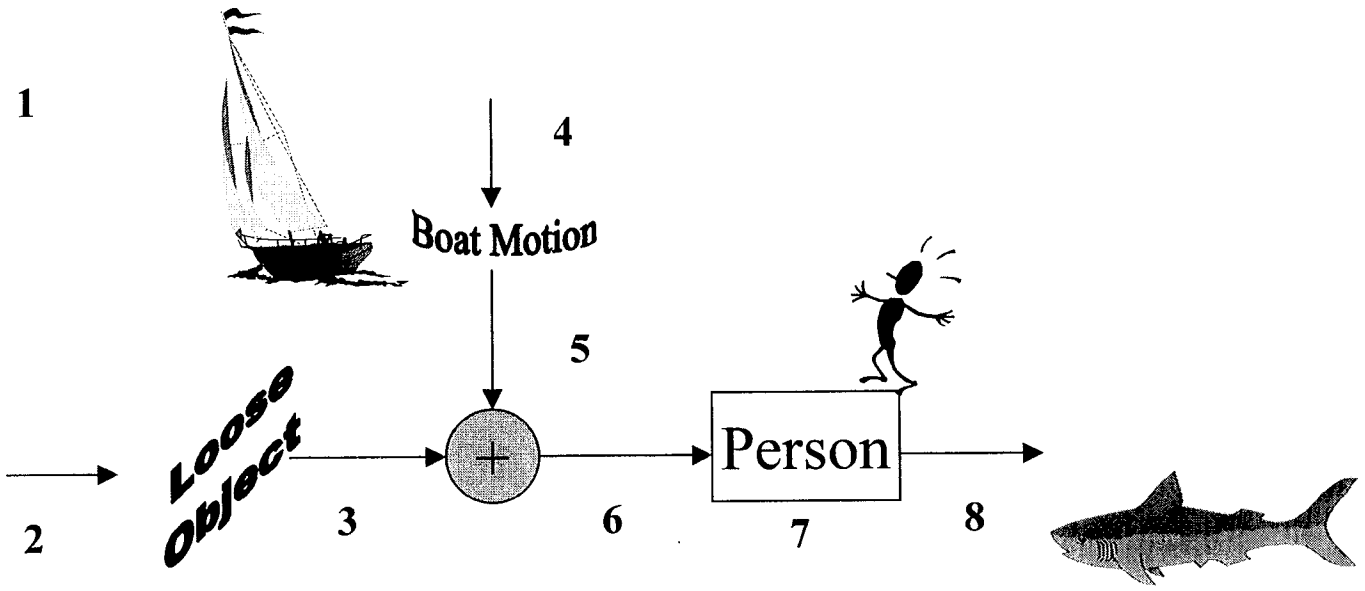
3.b. *Example: Falls Overboard*

Figure II.C.5 indicates factors involved in the accident category "Falls (Overboard and Within Boat)." As explained in Section 2.b, preceding, this Figure explores three basic ways in which a fall can be initiated. As an example of how one kind of qualitative analysis could be useful, consider just the accident case in which a loose object, in motion in the boat due to the boat's motion, hits a boater and causes him to fall or be knocked overboard. (The "loose object" could be something (or another person) carried in the boat, or it could be a part of the boat that is free to move, such as the boom on a sailboat. The object could knock the person overboard or cause him to loose his balance or trip.) Figure II.C.6 is a simple logic diagram of this case. (It says that the object has to be loose, influenced by the motion of the boat and hit the boater, who may fall as a result.) The elements of this accident are identified by the eight states listed in the Key to the figure. The flow of events is apparent, as are the necessary conditions of the accident.

This circumstance is presented in another way in the decision diagram of Figure II.C.7. Here, the logic of the situation is presented as a series of questions. "Yes" answers are required to all of these questions in order for the accident we are considering to come to completion. A "No" answer to any question will prevent the accident. Assuring safety becomes a matter of breaking the causal chain by assuring a "No" answer at some point. There are generally a number of ways in which this might be done at each step/link in this chain, "interventions" in the situation to improve safety. Identifying them is a matter of asking "How can this be prevented?" Solutions can be found by brainstorming "What if?" possibilities. For example, step 3 asks "Is the (already loose) object thrown about (by the boat's motion)?" A "No" answer could be caused, for example, by restricting the object's potential for further motion toward the person. Asking similar questions along the chain would result in a number of possible solutions to this safety problem. These could be weighed as to which is most practical or effective. This kind of consideration can be extended to conditions before and after the accident, as well. (Developing alternative solutions will be discussed in Chapter IV.)

Figure II.C.6:

Falls-Overboard - Struck by Loose Object Case Logic Diagram

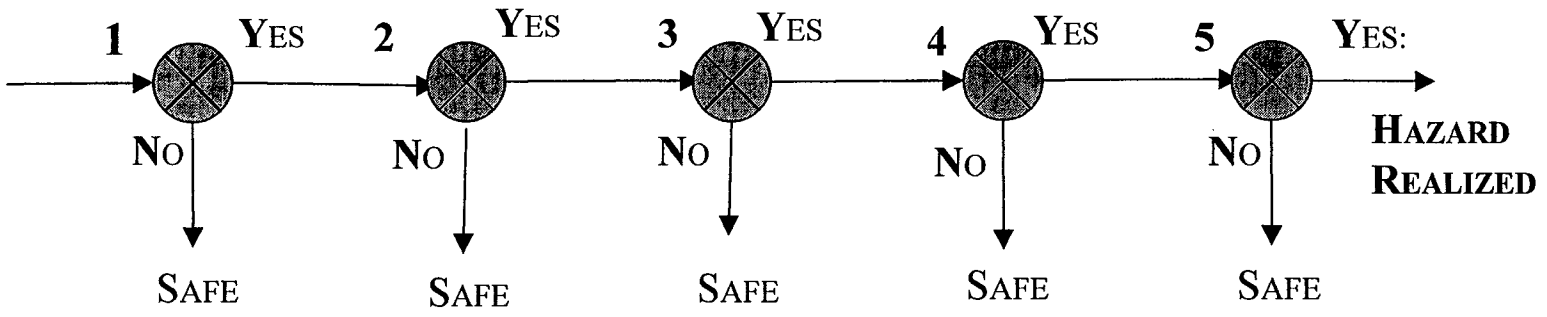


Key: 1. Present in Environment
2. Objects Onboard
3. Object Free to Move
4. Motion of Environment
5. Motion of Boat
6. Resultant Motion of Object
7. Object Impacts Person
8. Person Falls Overboard

Figure II.C.7

Falls-Overboard: Struck by Loose Object

Decision Diagram



Key: Answer these questions "Yes" or "No":

1. Boat Movement?
2. Loose Object Onboard?
3. Object Thrown About?
4. Object Hits Person?
5. Person Knocked Overboard?

(Beyond the scope of this illustration are questions such as "Is the person wearing a PFD ?" or "Is the person recovered after he falls overboard?")

NOTE: (1) ANY "NO" ANSWER TO QUESTIONS 1 - 5 WILL BREAK THE CAUSAL CHAIN THAT RESULTS IN THE PERSON BEING THROWN OVERBOARD, PREVENTING THAT ACCIDENT.

(2) THERE ARE MANY POSSIBILITIES FOR INTERVENTION AT EACH JUNCTURE.

(3) THIS IS ESSENTIALLY THE SAME SITUATION AS WHEN THE PERSON IS HIT BY AN UNSECURRED PART OF THE BOAT, LIKE A BOOM, OR BY ONE PERSON BEING (PASSIVELY) THROWN AGAINST ANOTHER.

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Chapter III: Analysis of Human Error in Boating Safety

A. Introduction

The largest single source of risk in recreational boating is human error. What contributes most heavily to boating accidents is failure to exhibit the behavior needed to minimize risk, such as not putting on a life preserver, overloading a small boat, or setting out in rough weather. Yet most of the behavioral shortcomings leading to recreational boating accidents do not appear in the statistical summaries presently employed in the analysis of risk. Inability to identify these shortcomings hampers our ability to address them in boating safety efforts. For, example, while we know that capsizing is a major cause of recreational boating fatalities, the statistics that tell us so are not very enlightening as to the reasons why boats capsize. Human error in this regard covers a wide range of behaviors, including standing up at the wrong time, steering a wrong course through waves, and setting out under the wrong conditions. Combating the various errors involves different approaches to instruction, regulation and vessel design.

Recreational boating accidents are far from unusual in the involvement of human error. Indeed, accidents of all types — motor vehicle, household, occupational, skiing — are primarily the result of human error. Yet, relatively little effort has been made to catalogue accidents producing those errors. One of the main reasons is the perishable nature of error information. In the aftermath of most accidents, the physical structures are available for study. Investigators can examine cars, boats, roads, waterways and other elements of the physical environment for their contribution to accidents. However, the behavior leading to accidents has vanished and can only be inferred from circumstances, along with testimony of participants or witnesses. A second reason for the lack of information on behavioral contributors to accidents is the wide range of individual contributors. Coding and analyzing what amounts to highly qualitative information has been difficult. Yet human error information can be highly valuable.

In the motor vehicle realm, a landmark study by Treat et al. (1977) analyzed close to a thousand accidents in depth for the driver errors involved and categorized the results. Up to that time, speed had been considered the major contributor, based perhaps upon the most serious, largely fatal accidents. But the Treat study revealed that visual shortcomings were far more important. The two leading causes were failure to look the right place at the right time and failure to recognize dangerous situations when they arose. This information had an enormous impact upon efforts to inform and educate the motoring public in good visual search practices and hazards. A special analysis by Drahos and Treat (1975) analyzed a subset of accidents for errors in last second emergency avoidance maneuvers.

B. Sources of Accident Information

Access to information concerning human error is available in most accident reports through narrative summaries prepared from information furnished primarily by investigating officers. Heretofore, this information had not been entered into the computerized files maintained by the state agencies responsible for maintaining boating accident records. It has therefore been missing from the records forwarded to the U. S. Coast Guard. However, this picture has changed with the introduction of the Boating Accident Report Database (BARD). This data base contains information recorded in the Boating Accident Report (BAR) completed by those investigating boating accidents within each state and filed with the cognizant state agency. In participating states, specialists enter data from the BARs into an automated file, a copy of which is forwarded to USCG on an annual basis. The file contains information concerning activities and conditions prevailing at the time of the accident, PFD use, identification and characteristics of the operator and the boat, identification and descriptions of any dead or injured, and the extent of damage.

The BARD file is the boating counterpart to the Fatal Analysis Reporting System (FARS) and the National Automotive Sampling System (NASS), which maintain data on fatal and non-fatal motor vehicle crashes. Access to these data bases by the scientific community has led to their use in examining the conditions under which motor vehicle crashes occur, including the involvement of alcohol and use of safety belts (the highway counterpart of PFD's). However, unlike the FARS and NASS, the BARD calls for entry of narrative descriptions for all accidents, with a separate entry for fatalities. The BARD narratives are taken from the narratives of Boating Accident Reports (BARs) and entered into the BARD data base by personnel of the cognizant state agency. Not all states have followed this practice. As recently as the 1997 file, only a little over half of the reports of individual accidents were accompanied by narratives. However, each year more states are providing information on more accidents.

The computerized narratives necessarily abbreviate the hard copy versions of the original state reports. Small samples of hard copy and computerized narratives from three states were reviewed to see how well the latter summarized the former with respect to descriptions of boater error. The outcome was quite favorable. The information bypassed consisted primarily of administrative details, the absence of which did not detract from the ability to identify errors. Where human error information was missing from narratives, it was generally missing from the hard copy as well.

It is apparent the BARD represents a significant technological advance in accident data collection and processing. The electronic filing of narrative information is unique. The counterpart to BARD in the highway accident realm, FARS and NASS, provides no narrative information and therefore no useable description of driver errors. The availability of BARD will allow the analysis of boater errors from the full range of accidents reported each year. The ability to process large numbers is extremely valuable since it allows boater errors to be subdivided by various characteristics of boats, boaters, waterways and environment, while still having enough cases in each subcategory for reliable estimation of risk associated with each error.

One additional source of information on boating accidents is the Marine Safety Information System (MSIS) maintained by the USCG. These reports, prepared from investigations conducted by Marine Safety Offices focus primarily on accidents involving commercial vessels.

Recreational boating accidents in MSIS are largely restricted to those involving both recreational and commercial vessels. The project staff searched the 1997 MSIS and BARD files for accidents in common, and compared the narrative information provided for each of six accidents found in the two files. The purpose was to see how closely the accident information correlated, whether there were gaps in the information from either source that the other source could fill, and whether the MSIS information would indicate that significant errors were being made in the coding of cases using BARD narratives alone. While the MSIS narratives were more voluminous, the additional information would not have substantially altered the coding of errors. It is apparent that the BARD file has been sufficient for the analysis of recreational boater errors in accidents recorded by the MSIS.

C. Analysis of Accident Data

The analysis of accidents to identify causes can take two forms. One involves *analysis of accident frequency*, counting the numbers of accidents associated with various aspects of boating. Large numbers associated with a particular aspect points to a possible cause. For example, if accident records show a large proportion of Personal Watercraft (PWC) accidents involve collisions with other boats there is reason to suspect that mishandling in the presence of other vessels is a significant source of accidents. The second form of accident analysis involves the *investigation of accidents* for the conditions under which each occurs. When a boater pulls out of a slip suddenly, ramming another boat, and investigation reveals that the offending skipper failed to see the other vessel, inadequate visual search can be considered a cause. Both forms of accident analysis can be applied to the BARD data.

1. *Analysis of Accident Frequency*

One source of information on the nature of boater error is accident frequency, that is, numbers of accidents occurring within some period. A high frequency associated with some aspect of boating provides a clue as to the source of risk. The term risk, as applied to accident analysis refers to the probability that accident loss will occur where the possibility of an accident exits. Heavy weather entails greater risk than calm weather because the probability of injury or drowning is greater. Wearing a PFD reduces risk because it lessens to the probability of drowning. While analysis of accidents cannot tell us directly what errors caused them, it can provide useful leads. It cannot reveal all errors leading to accidents, it can identify many of them. If the risk of accident loss in small boats is increased by heavy wind, then operating a small boat under such conditions can be considered an error. Similarly, if risk is increased by failure to wear a PFD, then such a failure can be considered an error. The automation of the BARD file greatly facilitates analysis of accident frequency. A variety of available statistical programs can be applied to BARD files to count the numbers of accidents in various categories of boats, boaters, waterways and environment, as well as combinations of categories. For example, the number of accidents involving open motor boats can be totaled, as well as subdivided by length of boat, weather conditions or combinations of these and other variables.

1.a. *Risk Estimation*

The number of accidents itself is not an indication of risk. The largest share of fatal accidents involves small open boats, not because they are inherently more risky than others, but because they are involved in more boating activity than any other type of boat. Accidents also occur most often in good weather because that is when most boating takes place. Estimation of risk through analysis of accident frequency requires comparing the numbers of accidents with the opportunity for accidents to occur, referred to as "accident exposure." Within the field of transportation, exposure is generally measured in terms of distance traveled, with risk expressed in terms of accidents per vehicle miles traveled. However, recreational boaters are exposed to accidents whenever the boat is in use, whether or not it is moving, and risk is more appropriately expressed in units of time rather than distance. At present, reliable estimates of boat use in units of time for all categories of boats are unavailable. However, efforts to gain such measures are underway.

One of the best known and most valuable applications of accident and exposure information to the estimate of risk is in the area of alcohol impairment, where Borkenstein and his associates (1974) compared the blood alcohol levels of accident victims with those taken from drivers operating vehicles under the same conditions (time, place, make of car, etc.). It was through such comparisons that the risk of fatal accidents among the intoxicated was determined to be ten times that of drivers not intoxicated. The same type of analysis is currently being carried out with boaters in Maryland and North Carolina by Johns Hopkins University.

One aspect of risk that accident analysis *can* estimate from available data is that of various consequences *when accidents do occur*. If we want to know the risk of drowning in an accident we can compare the numbers of drownings with exposure to drowning. For example, suppose we want to determine the effect of PFD use upon the risk of drowning. We can do this by comparing the relative numbers of drownings in accidents where they were and were not used. As a hypothetical example, assume that BARs for a particular year report 2,000 falls overboard of which 75 boaters drowned wearing PFDs, 425 drowned without them, 450 survived with them and 1050 survived without them. The relative risk ratio would be (450/1050) / (75/450) = 2.4, meaning that the chances of surviving in the water would be almost two and one-half times greater wearing a PFD.[38] With these hypothetical odds, failure to wear a PFD where there's a significant chance of falling overboard can be considered an error.

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[38] The BARD currently records information on PFD use only for fatalities, even though the BAR collects such information for all those involved in reported accidents

1.b. *Problem Identification*

The inability of accident data to furnish precise estimates of risk associated with various aspects of boat operation doesn't mean that it is not of value in identifying forms of dangerous error. The fact that PWCs are responsible for half of all reported accidents involving collisions with other vessels points to a problem, as does the fact that collisions account for almost two-thirds of all PWC accidents. Whether PWCs present a particularly high risk of collision in the way they are operated, or whether they are just more exposed to collisions by where they operate it is clear that efforts to prevent collisions offer great potential payoff. Efforts to reduce risk would include better surveillance, greater separation, and improved communication, while attempts to reduce exposure would discourage operating in the vicinity of other vessels, including other PWCs.

Analysis of accident sources within category of boat operation can be particularly informative. While canoes account for less than 20% of capsize accidents, such accidents account for over half of canoe accidents, making the prevention of errors leading to capsize a potentially rewarding route to canoes safety. Similar breakdowns of accidents by types of waterway, time of day, and other conditions surrounding accidents can also help to guide safety measures. Analysis of accidents within the individual states can aid in targeting local safety efforts, including information and education programs focusing upon aspects of boating performance relating to the accidents identified. Precedence for such application of accident data can be found in the "problem identification" program undertaken in the mid 1970s by the National Highway Traffic Safety Administration to aid states in the analysis and interpretation of motor vehicle accident data in their state files. A set of automated data processing programs called the Data Analysis and Retrieval System (DART) was developed and a series of training programs administered to aid state personnel in their use.

Some skill in file management, data processing and statistics is required to make full use of the BARD files in problem identification efforts. To facilitate use of BARD by users not possessing these abilities, the USCG has developed the Boating Risk Analysis Information System (BRAINS). The BRAINS allows the relative frequency of accidents to the estimated as a function of various boating characteristics. Information for the BRAINS comes from the Boating Accidents Reports (BARs); at present, the BRAINS data base includes accidents reported in BARs during the period 1988 - 1994. Accidents are divided into nine overlapping categories: Grounding, Boat/propeller striking, Water in Vessel, Fire/Explosion, Injury (General), Injury (PWC), Collision (General) Injury (PWC) and Drownings. Within each category, BRAINS will provide the proportion of accidents falling into categories as defined by the user. For example, Drownings can be classified by boat type, PFD use, water temperature and presence or absence of rough water, strong current, water skiing, racing, drifting, voluntarily leaving boat, medical complications, use of alcohol, swimming or diving, or improper use of PFDs. The BRAINS analyses are limited to a predetermined set of data elements for each accident category. The elements selected are those considered to be of particular interest in examining accidents in a given category.

2. *Analysis of Individual Accidents*

While the analysis of accident frequencies can be useful in identifying aspects of boating where errors are occurring, it rarely succeeds in identifying the specific errors involved. Efforts to reduce capsize accidents in canoes would benefit from information identifying just what leads to such accidents — overloading, distribution of loads, standing up, drinking. The second form of accident analysis involves investigation of individual accidents to identify the conditions surrounding individual accidents for clues as to the causative factors. This is the way in which causes of catastrophic accidents involving aircraft, ships, railroads, are identified, along with some motor vehicle accidents of particular significance, e.g. trucks with hazardous materials or school buses. The primary source of data on such accidents is the National Transportation Safety Board (NTSB), which employes teams of professional accident investigators for the purpose. Ship accidents investigated by MSOs and reported in the MSIS also tend to fall into this category.

The numbers of accidents reported through these sources is far too small to infer cause from comparison of accident experience with exposure. Rather, teams of trained specialists determine cause through in-depth investigations of the circumstances surrounding the accidents. Judging the role of human error is usually left to human factors specialists, knowledgeable in human behavior in the particular activity in the domain of the accident investigated, e.g. motor vehicles, aircraft, work-related.

Similar information on human error is usually provided in routine reports prepared by police called to the scene of motor vehicle accidents. In the case of boating accidents, the results appear in written narratives that form a part of the BAR, and are increasingly entered into the BARD data base. The information appearing in narratives is particularly valuable in reckoning the contribution of human error to boating accidents. While the accidents are not investigated in the same depth as more catastrophic accidents, their larger numbers allow the errors identified to be assessed for the magnitude of their accident involvement.

While the narrative descriptions of accidents in the BARs and the BARD system provide a basis for identifying human error, they do not in their hard copy form provide a practical source of information to those wishing to apply accident experience to preventive efforts. Since various accidents involve a wide variety of human errors, it takes a lot of reports to identify the full range of errors that occur. Moreover, to focus preventive efforts where they will do the most good, the relative numbers of the different errors need to be tabulated. Doing this with any validity would require analyzing thousands of reports. Since one cannot expect regulators, educators, writers and other interested parties to pour over stacks of reports, some way for summarizing the errors revealed in their content is needed.

D. Exploratory Analysis of Boater Error

As a part of the project being described an analysis of the narrative information provided in the BARD files was undertaken. The purpose was to develop methods for coding and classifying boater errors, and gain some estimate of the potential value of such information in the prevention of boating accidents.

1. *Coding of Boater Error*

The first step in the process of coding and classifying boater error was to create a classification of boater errors that could be applied to the BARD narrative reports. It is difficult to arrive at a classification system without knowing something about the items to be classified; it is equally difficult to examine a vast array of items themselves without having some idea as to how they might be classified. The way out of this apparent dilemma is typically through an iterative process, starting with an initial classification based upon what is known of the items, attempting to classify items based upon it, and continually modifying the classification to accommodate the items. This iterative process was employed with the BARD narratives. An initial classification was based on what is known of boating accidents, borrowing somewhat from classifications of other types of accidents. The BARD accidents were then sorted using the preliminary classification, with repeated revisions of the coding process as individual accidents revealed the need for additional categories, as well as subdivision or combination of existing categories.

The classification was not one of errors but of the *behaviors required to operate a boat safely.* The behaviors form a more cohesive taxonomic structure than do the errors. Moreover, any of the behaviors required for safe operation are candidates for accident producing errors, whether or not an error has actually been recorded. An initial classification was generated with the aid of an index developed from materials describing the requirements of safe boating. Educational materials were most valuable in this regard. To test the classification, a sample of 1,000 accident reports was drawn from the 1997 BARD file. It included all of the 689 fatal accidents having narratives, then a random sample of 311 non-fatal injury accidents to reach the total of 1,000. A special format was created in Microsoft Access Database Management Program to allow the accidents to be classified in terms of the initial coding system. The format included for each of the selected accidents, the narrative, a few objective data elements (e.g. type of vessel) and the original accident report number (the special format was developed purely for use in the assessment and has no application outside of the specific use for which it was developed). If identification of human error were to become standard practice, a provision would ultimately be made for entering codes as part of the basic BARD data entry process.

The accident categories in the boater error classification system were assigned code numbers. The project staff then examined the narrative of each accident as it appeared in the file of 1,000 accidents and assigned error code numbers to each accident based upon the narrative. Since more than one error can contribute to an accident, the Access format provided space for up to three error codes for each accident. The order in which they were listed was purely arbitrary; no attempt was made to weight errors in terms of their contribution to the accident. In almost all cases, the elimination of any one of multiple errors would have prevented the accident from occurring. For example, where an accident resulted from setting out in rough weather, not

distributing weight properly, or improper handling of the boat, avoiding any of these errors might have prevented a boat from swamping.

As the classification progressed, codes needing revision were identified and discussed. The system was then revised and the narratives were re-coded (a change easily made electronically). The classification system and codes that resulted from the iterative process described appears in Figure III.C.1. It is clearly a long list – approximately 300 codes. However, the list reflects the large array of specific behaviors involved in operating all types of boats. A fuller description of each specific error appears in Appendix C.

Development of the codes, and classification of accident-related behaviors in terms of the codes, was handled by a team consisting of (1) a retired USCG Captain with an extensive background in recreational boating safety, a lifetime boater himself, and (2) a behavioral scientist with a 35-year history of research in transportation safety, including motor vehicle accident analysis, as well as 60 years of recreational boating experience.

The codes shown in Figure III.C.1 represent a hierarchy of behaviors.

1000 PREPARATION FOR BOATING — advance preparation for long term boating
2000 PREPARING FOR OPERATION — preparation for a specific boating occasion
3000 SAFE OPERATION — actual operation of the boat under normal conditions
4000 OCCUPANT PROTECTION — protecting the occupants against death or injury
5000 ENVIRONMENTAL LIMITATIONS — safely operation the boat in rough weather and limited visibility
6000 EMERGENCIES — responding quickly and effectively to sudden danger

The first three categories represent a sequence of behaviors leading up to and including safe boat operation while the third involves protecting occupants against the consequences of unsafe operation. The last two superimpose upon basic boat operation the special demands of the environment and emergency situations. The more commonly known division of events into pre-accident, accident, and post-accident is useful in classifying the full range of influences upon safety. However, boater behavior falls largely in the pre-accident phase. Safety in "accident" phase is largely a matter of equipment; in motor vehicles it is primarily crash worthiness and safety restraints. The "post" phase is primarily the province of medical and rescue services.

Among the codes, those in bold represent major categories, while those underlined are sub-categories. The remainder are specific behaviors. For example, within the 1000 category, preparation for boating, the category 1100 making sure the vessel is outfitted for PFDs contains the specific behaviors 1110, making sure of the correct number and type, 1111, making sure they are wearable and so on are specific behaviors subject to boater error. The next major category, 1200 fire safety has several subcategories, 1210 - 1240 and 1260. However, 1250 making sure that gasoline engines are equipped with back flame arresters is a specific behavior.

Figure III.C.1: PRELIMINARY ERROR CODES

1000 PREPARATION FOR BOATING
1100 PFD Outfit
1110 Number and type
1120 Wearable
1130 Throwable
1140 Reflective material
1150 Whistles and lights
1160 Serviceable
1170 Inflation devices
1180 Accessible
1200 Fire Safety
1210 Extinguishers
- 1211 Number and type
- 1212 Inspected
- 1213 Charged

1220 Stoves
- 1221 Filling
- 1222 Design
- 1223 Fuel storage
- 1224 Distribution
- 1225 Fuel handling

1230 Engine fuel
- 1231 Storage
- 1232 Distribution
- 1233 Handling

1240 Electrical (non OEM)
- 1241 Protection devices
- 1242 Wire sizing
- 1243 Battery shorting

1250 Back flame arrestor
1260 Vapor removal system
- 1261 Complying installation
- 1262 Serviceability

1300 Controls
1400 Lights
1410 Navigation
- 1411 Required types
- 1412 Serviceability

1420 Flashlights, spotlights
1430 Anchor lights
1500 Sound Equipment
1600 Safety Outfit
1610 Grab rails, lifelines, toerails
1620 Throw line
1630 MOB recovery
1640 Distress signals
1650 Radio
1660 First aid kit
1670 Pumps/bailers
1680 Anchor
1690 Paddle
1700 Navigation
1710 Compass
1720 Depth device
1800 Boat
1810 Watertight integrity
1820 Flotation materials
1830 Gear stowage
1900 Operator
1910 Skill
1920 Physical ability
2000 PREPARING FOR OPERATION
2100 Crew
2110 Assuring Physical abilities
2120 Assuring Skill
2200 Needed Charts
2300 Route Checks
2310 Depths
2320 Surface obstructions
2330 Underwater obstructions
2340 Waterfalls and dams
2350 Electric wires
2360 Other hazards
2370 Fast water/rapids
2400 Weather Check
2410 Current weather
2420 Forecasts
- 2421 Immediate
- 2422 Long range

2430 Current checks
- 2431 Force
- 2432 Direction.

2500 Special Equipment
2510 Exposure clothing
2520 Harnesses, jacklines
2530 EPIRB
2540 Life raft
2550 Survival suits
2560 Storm gear
2570 Helmet
2600 Portable Communications
2700 Fuel
2710 Fuel check
2720 Fueling
- 2721 Engine off
- 2722 Close hatches
- 2723 No flames

2800 Float Plan
2810 What
2820 When
2830 Who
2900 Decision to Operate
2910 Operator
- 2911 Physically able
- 2912 Necessary skills

2920 Boat
- 2921 Design
- 2922 Condition

2930 Weather
2940 Destination
- 2921 Navigability
- 2922 Boat/Equipment
- 2923 Crew

3000 SAFE OPERATION
3100 Boat
3110 Weight
- 3111 Amount
- 3112 Distribution

3120 Entry
- 3121 Procedure
- 3122 Handholds
- 3123 Sequence

3200 Basic Control
3210 Starting
- 3211 Transmission in neutral
- 3212 Blower before starting
- 3213 Sniff bilge

3220 Motion control
- 3221 Direction
- 3222 Speed
- 3223 Thrust for steering
- 3224 Acceleration

3300 Safety Practices
3310 Speed
- 3311 Posted limit
- 3312 Boat characteristics
- 3313 Congestion
- 3314 Close to boat,
- 3315 Wakes
- 3316 Land
- 3317 For maneuver

3320 Turning
- 3321 Control
- 3322 Congestion/ hazards
- 3323 Boat characteristics

3330 Lookout
- 3331 Looking ahead
- 3332 Before turning
- 3333 Around
- 3334 Vision obstructions
- 3335 Small objects/PIW
- 3336 Checking depth/position

3350 Chart Navigation
- 3351 Correlate observations
- 3352 Chart reading
- 3353 Plot fix
- 3354 Determine course
- 3360 Hazard recognition

3370 Allowing Space
- 3371 From other boats
- 3372 From land
- 3373 From swimmers

3400 Rules of the Road
3410 Collision risk
3420 Which rule/action
- 3421 Overtaking
- 3422 Maneuverability rules
- 3423 Arbitrary rules
- 3430 General prudential

3500 Rope/Chain/Wire
3510 Securing end
3520 Body parts free
3530 Surges
3540 Easing
3550 Knot tying
3560 Staying clear

3600 Special Operations/Maneuvers
3610 Coming alongside
- 3611 Approaching slowly
- 3612 Approach angle
- 3613 Low speed steering
- 3614 Body parts clear
- 3615 Transfer to dock/boat

3620 Anchoring
- 3621 Ready anchor
- 3622 By bow

3630 Towing
3640 Unplanned events
3650 Waterskiing
- 3651 Location
- 3652 Regulations
- 3653 Obstructions
- 3654 Time of day
- 3656 Observation
- 3657 Conditions
- 3658 Operation
- 3659 Recovery from water

3660 Sailing
- 3661 Weight distribution
- 3662 Shortening sail
- 3663 Spilling wind
- 3664 Gybe control

3670 Wake jumping

3700 Operating at night
3710 Running lights
- 3711 Configuration
- 3712 Operation

3720 Interpreting others
3730 Anchor lights
3740 Unconfusing displays
3750 Unlighted objects
3760 Lighted objects
3770 Adjust speed
3780 Illuminating self

3800 Communicating
3810 To Crew
3820 To other vessels
- 3821 Whistle signals
- 3822 Radio

3821 Hails/hand signals

4000 OCCUPANT PROTECTION

4100 Falls Overboard
4110 Handhold/footing
4120 Inside cockpit/cabin
4130 Remain seated

4200 Wear PFD when...
4210 High risk of immersion
4220 Difficulty finding in water
4240 Unable to swim
4230 Difficulty recovering from water
4240 Unable to swim
4250 Cold water
4260 Unconscious

4300 First Aid
4310 Sun/heat/hypothermia
4320 CPR
4330 Other first aid
4340 Call for help

4400 Voluntarily Entering Water
4410 Avoid strong tides
4420 Swim upstream
4430 Trail line
4440 Facilitate egress
4450 Flotation
4460 Swimming after boat
4470 Stay clear of boat.

4500 Use of Alcohol
4510 Control own
4520 Control others'
4530 Recognizing signs
4540 Protecting impaired

5000 ENVIRONMENTAL LIMITATIONS

5100 Rough Conditions
5110 Recognizing onset
5120 Estimating duration
5130 Responding
- 5131 Wearing PFDs
- 5132 Seeking shelter
- 5133 Securing vessel
- 5134 Adjusting speed
- 5135 Adjusting direction
- 5136 Balancing boat
- 5137 Bailing/pumping

5200 Limited Visibility
5210 Avoid obstructed area
5220 Lights/sound signals
5230 Slow speed
5240 Listen (no engine)
5250 Leave shipping channel
5260 Anchor and wait

6000 EMERGENCIES

6100 Falls Overboard
6110 Pass the word
6120 Throw device immediately
6130 Post lookout
6140 Stop/turn immediately
6150 Approach (power)
6160 Approach (sail)
6170 Fix/radio call
6180 Hoisting preps
6190 Drill

6200 Survival in Water
6210 Boat for flotation
6220 Other objects
6230 Clothes for floatation
6240 Gaining conspicuity
6250 Conserving energy
6260 Conserving heat
6270 Swim across current
6280 Entanglement

6300 Extinguishing Fires
6310 Use extinguisher
6320 Water for alcohol only
6330 Eliminate sources
- 6311 Fuel supply
- 6312 Electrical source
- 6340 Use extinguisher properly

6400 Seeking Help
6410 Radio at first sign
6420 Distress signals
6430 Use of EPIRB

9000 Not Classifiable
9100 Insufficient Information
9200 Act of Nature

2. *Error Analysis Methods*

Once an acceptable set of codes was devised, the errors identified in the sample of 1,000 accidents were classified in terms of the system. During the analysis, 58 accidents were eliminated because of the lack of error information in the accident narratives, leaving a total of 942 accidents. Since many accidents involved more than one error, the number of errors totaled 1739.

Different types of vessels expose boaters to different conditions and therefore different types of errors. For the results of the analysis to be useful, errors need to be subdivided by vessel type. Errors were initially coded into the 12 categories of vessel appearing on Boating Accident Report: rowboat, canoe/kayak, inflatables, PWCs, open motorboats, pontoon boats, cabin motor boat, houseboat, auxiliary sail, and sail-only, plus "other," "unknown," and cases where error data were missing. To allow results to be more readily interpreted, the number was reduced to five by combining the first three into a "Small Open" boat category, open motor and pontoon boats in to an "Open Power" category, the houseboat and cabin motorboat into a "Cabin Power" category, and the two types of sailboats into a single "All Sail" category. While the combined categories are not entirely homogeneous (rowboats often use outboards where canoes and kayaks rarely do) some combination was needed to obtain enough errors in each category to allow subdivision by error type. In subsequent analyses, with larger numbers of accidents, these two might be separated.

Where more than one boat was involved in an accident, only the boat identified as the primary "at fault" boat was included in the analysis. This step excluded what might be called "defensive" errors, that is failure to take steps that might have protected the victim from being involved in the particular accident. However, multi-vessel accidents were in the minority, and inferences as to whether or how the innocent party might have prevented the accident were not easily made from the narrative information provided.

A complete breakdown of errors, subdivided by category of boat by Code appears in Appendix D. The Appendix lists both the number and percent of errors attributable to the behavior listed. The percentages are column percents, meaning the percent of all errors involving a particular type of boat that are attributable to the behavior category listed. For example, not having the required number and type of PFD (Code 1110) accounts for 1.4% of all errors and 6.1% of errors involving small open boats (canoe/kayak, rowboat, inflatable). Such information clearly identifies the type of boat that represents the most fruitful target of inspections for PFDs. While other types of vessel may also be deficient in this category, the deficiency does not appear to have played a major role in leading to fatal accidents. It is very difficult to grasp the nature of boating accident causation from the volume of data presented in the complete breakdown of errors. The majority of errors appearing in the classification occurred too infrequently to provide reliable estimates of magnitude within boat category. A separate breakdown was generated for those errors occurring ten or more times. This analysis appears in Figure III.C.2.. As in Appendix D, both numbers and percent of accidents are shown and the percentages are the way in which errors leading to accidents of a particular boat break down.

Figure III.C.2: BEHAVIORS SUBJECT TO ERROR TEN OR MORE TIMES
Number of accidents and the percent of accidents involving each error, by boat type

	Unk-nown	All Sail	Open Small	Open Power	Cabin Power	PWC	Total
Having the correct number and type of PFDs			18	6			24
			6.1%	.8%			1.4%
Assuring that controls are in operating condition			1	12	1	2	16
			.3%	1.6%	1%	.4%	.9%
Operator has needed knowledge and skill	1	4	6	5	2	38	56
	1.8%	5.9%	2.0%	.7%	2%	8.3%	3.2%
Crew possesses the skill needed for the operation	2		1	2		16	21
	3.6%		.3%	.3%		3.5%	1.2%
Checking route for overhead / underwater obstacles	1		1	9	1	4	16
	1.8%		.3%	1.2%		.9%	.9%
Considering design of the boat relative to intended use			9	2			11
			3.1%	.3%	1%		.6%
Considering the weather in deciding whether to operate	1	1	6	4	1		13
	1.8%	1.5%	2.0%	.5%	1%		.7%
Considering ability of the waters to be safely navigated		1	14	2		1	18
		1.5%	4.8%	.3%		.2%	1.0%
Considering the boat/equipment in relation to destination.			9	1		2	12
			3.1%	.1%		.4%	.7%
Limiting the total weight of passengers.			9	4			13
			3.1%	.5%			.7%
Controlling the yaw of the boat in a safe manner..			3	12		14	29
			1.0%	1.6%		3.1%	1.7%
Controlling the thrust where needed for steering force						12	12
						2.6%	.7%
Controlling the rate of change in speed	1			5	1	3	10
	1.8%			.7%	1%	.7%	.6%
Adjusting speed to limits imposed by nearby boats	2	2		6		30	40
	3.6%	2.9%		.8%		6.6%	2.3%
Adjusting speed to limits imposed by waves or wakes..	2			20	2	28	52
	3.6%			2.6%	2%	6.1%	3.0%
Adjusting speed to maneuvers to be performed.				7		5	12
				.9%		1.1%	.7%
Adjusting speed to the proximity of land.	1			6		3	10
	1.8%			.8%		.7%	.6%
Adjusting the rate of turn to maneuver limitations	1			6	1	3	11
	1.8%			.8%	1%	.7%	.6%
Looking ahead to see obstructions to the intended path.	2	1		13	1	13	30
	3.6%	1.5%		1.7%	1%	2.9%	1.7%
Looking to the side and behind before starting a turn.	2			6		15	23
	3.6%			.8%		3.3%	1.3%
Exercising 360-degree surveillance.	1			6	1	7	15
	1.8%			.8%	1%	1.5%	.9%
Overcoming vision obstructions to assure a clear view.				4	2	7	13
				.5%	2%	1.5%	.7%

Looking periodically to check position/ depth.	1		1	35	9	9	55
	1.8%		.3%	4.6%	8%	2.0%	3.2%
Allowing sufficient space from other boats	6			15	1	77	99
	10.9 %			2.0%	1%	16.9%	5.7%
Allowing sufficient space from fixed structures	1			13	2	10	26
	1.8%			1.7%	2%	2.2%	1.5%
Avoiding being trapped by current		1	23	9			33
		1.5%	7.8%	1.2%			1.9%
Adhering to arbitrary rules for right of way	1			6	1	9	17
	1.8%			.8%	1%	2.0%	1.0%
Keeping body parts free from being struck/ entangled.	2	1	3	5		1	12
	3.6%	1.5%	1.0%	.7%		.2%	.7%
Coping safely with unplanned events.	3	2	13	25	3	2	48
	5.5%	2.9%	4.4%	3.3%	3%	.4%	2.8%
Operating in areas free of, and avoiding obstructions.	1			11		2	14
	1.8%			1.4%		.4%	.8%
Boat or skier safely jumps waves or wakes.						22	22
						4.8%	1.3%
Locating and/or detect unlighted objects				10	6		16
				1.3%	6%		.9%
Adjusting speed to limitations of night visibility	1			24	9	1	35
	1.8%			3.2%	8%	.2%	2.0%
Assuring a secure grip/ footing on the boat when needed.		1	1	6	3	1	12
		1.5%	.3%	.8%	3%	.2%	.7%
Remaining seated when stability or conditions warrant.			13	16			29
			4.4%	2.1%			1.7%
Wearing PFD when conditions create significant risk.		2	26	19	1	4	52
		2.9%	8.9%	2.5%	1%	.9%	3.0%
Wearing of PFDs by occupants unable to swim.			14	12	1		27
			4.8%	1.6%	1%		1.6%
Wearing PFDs in cold water	1	1	12	20		1	35
	1.8%	1.5%	4.1%	2.6%		.2%	2.0%
Using some form of flotation where conditions warrant	2		4	7	1		14
	3.6%		1.4%	.9%	1%		.8%
Controlling the consumption of alcohol.	2	5	25	74	9	20	135
	3.6%	7.4%	8.5%	9.7%	8%	4.4%	7.8%
Handling rough conditions in general		1	2	9	1		13
		1.5%	.7%	1.2%	1%		.7%
Responding to rough conditions when they occur.		2	1	6	1	4	14
		2.9%	.3%	.8%	1%	.9%	.8%
Assuring that PFDs are worn in rough conditions			1	9			10
			.3%	1.2%			.6%
Adjusting the speed to wind and water conditions.				8	2	3	13
				1.1%	2%	.7%	.7%
Using the boat for flotation (e.g. capsized boat).		1	6	11			18
		1.5%	2.0%	1.4%			1.0%
Seeking help in an emergency.		3	3	2		2	10
		4.4%	1.0%	.3%		.4%	.6%
Total errors	55	68	293	759	108	456	1739
	100%	100%	100%	100%	100%	100%	100%

All of the numbers extracted for the table refer to *specific behaviors.* However, in the Appendix, specific behaviors are the lowest order in the hierarchy; the rest are categories of behavior. Where a number appears for a *category* of behavior it refers not to the total number of errors in that category but rather the number not included among the specific behaviors listed, in other words, "*miscellaneous.*" For example, in the case of PFD Outfit, code 1100 is the category of having PFDs aboard, with the specific behaviors are 1110, having the proper number and type, 1160 making sure they are serviceable, and 1180 making sure they are accessible. The four cases of errors classified as "1100 PFD Outfit"represent all errors related to having PFDs aboard that are not represented by the three specific behaviors listed , 1110, 1160, and 1180. This practice made it unnecessary to lengthen the table with a miscellaneous code for each category. The table does not provide total errors within categories. To do so makes the tacit assumption that the behaviors within a category are somewhat homogeneous. Such is not necessarily true. For example certain boaters may look out for things ahead (3331) and rarely look behind them before starting a maneuver (3332). A number for total lookout does not have any inherent meaning. Numbers for various individual behaviors can be combined in different ways for different purposes.

The column percentages in the table and Appendix D represent the percent of all errors committed relative to a particular type of boat. Of equal interest would be the percent of all *accidents* involving a given error. Such an analysis was conducted, and the results will be noted in further discussion. However, a table of accident percentages has not been added to the report since the accident percentages are highly correlated with the error percentages. There being fewer accidents than errors, each error represents a larger percent of accidents than of total errors. To determine the percent of accidents involving a particular behavior simply multiply the error percentage by 1.9, that is essentially *double the error percentage*. For example, where of PFD (Code 1110) accounts for 1.4% of all errors, it is involved in 2.8% of all accidents.

The present demonstration combined fatal and injury accidents. There is certain to be a significant difference between fatal and non-fatal accidents in the errors leading to them since the majority of fatals involve drowning where the non-fatals involve injury of some sort, or merely damage to the boat. Analyses performed in the future to guide accident prevention efforts would keep fatal, injury, and property damage accidents separate. To obtain enough fatals for reliable estimation of error involvement, data from several years would be combined. Three two five years would provide larger numbers and yet allow the comparisons across time periods needed to detect changes or trends in the types of errors occurring. The larger numbers of injury and property damage accidents would allow effective use of data from a single year. Where accidents involving particular error codes fail to appear even in large data bases, those codes might be eliminated from the list.

E. Results of Error Analysis

The purpose of the error analysis performed in this demonstration was solely to assess its potential value in identifying the behavioral contributors to boating accidents and ultimately helping to guide boating safety efforts. The numbers of cases studied is too small to provide reliable estimates of problem magnitude for most errors, particularly when classified by type of boat. However, the information gathered is worth reviewing as a demonstration of how it might be used.

The single most frequent error leading to accidents identified in accident reports is the misuse of alcohol, making up about 8% of all errors and contributing to 13.5% of all accidents.[39] This certainly represents a problem of underestimation since analysis of blood alcohol in boating fatalities reveals about a third of the cases being over the legal limit for intoxication. The underestimate reflects the difficulty of investigating officers to detect alcohol involvement, particularly in the case of fatalities. However, the relative involvement of different types of boats is informative. PWCs are relatively less involved in alcohol-related accidents than other vessels and cabin motorboats appear almost totally uninvolved.

The single most frequent operating error reported is failure to allow "sufficient space from other boats," usually resulting in collisions. While this error is represented to some extent in all powered boats, it is clearly over-represented in PWCs, where it accounted for approximately 17% of all errors and 28% of it's the accidents. It is almost a negligible error for all other categories. The large number of PWC accidents renders the percentages given reasonably reliable estimates of the magnitude of the problem. When we look down the list of most frequent errors to lack of knowledge and skill, we find that it was involved in 56 accidents, accounting for 3.2% of all errors committed. However, the danger was greatest in PWCs, where it accounted for about 9% of all errors and was involved in 17% of accidents. This probably comes as no surprise to those who recognize the lack of boating experience on the part of many, if not most, PWC operators. However, the BARD data provides documentary evidence of the problem magnitude. While percentage for sail boats also appears quite high, 5.9%, there were only 4 cases, too small a number to give a reliable estimate of involvement of skill and knowledge deficiencies. Two other frequent errors in which PWC operators were over-involved are not "Adjusting speed to limits imposed by nearby boats" and not "Adjusting speed to limits imposed by waves or wakes." This means that PWCs more than any other boat are vulnerable to accidents resulting from excessive speed in the presence of other boats and waves or wakes.

One error in which PWC are not disproportionately involved is not "Wearing PFD when conditions create significant risk." This was the most common error on small open boats (canoes, kayaks and rowboats), accounting for about 9% of errors and 17% of accidents. Another was not "Looking periodically to check position/ depth," accounting for 8% of errors

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[39] These figures come from a preliminary analysis of data from an on-going study by Johns Hopkins University. A report has not yet been published.

and 15% of accidents among operators of cabin powerboats. Errors on open powerboats were rather evenly distributed across categories. While this distribution may reflect the characteristics of the boat — somewhere between small open boats and cabin motorboats — it is also likely to be a product of the large numbers accidents and the smaller chance variation. The latter consideration underlies all of the percentages cited. With larger samples of accidents percentage differences between boat types in the frequency of errors is likely to decline.

F. Further Development

The development of a preliminary system for coding, compiling and analyzing data on recreational boating errors completes what was intended as an exploratory study. The results of the effort were instructive as to the potential of boater error analysis in the prevention of boating accidents and the steps that might be taken to realize that potential.

1. *Future Analyses*

Most of those engaged in the investigation of boating accidents are fairly knowledgeable of the most common boater errors. What a systematic analysis can provide is *quantification*. Being able to say that traveling in close company leads to PWC accidents is one thing; recognizing that it contributes to over a quarter of the accidents helps to (1) prioritize efforts to reduce this practice through education and enforcement and (2) track the effects of such efforts over time. It has become apparent in the analysis undertaken so far that the process can be highly enlightening as to the nature and distribution of boater errors. For example, while the inordinate numbers of PWC accidents is well known, and most of the errors leading to them have been identified, the role of not allowing enough space from other boats may not be fully appreciated. Such information can aid in targeting enforcement of regulations prohibiting operation close to other vessels.

1. a. *Scope of Analysis*

As previously noted, most of the accidents entering the present analysis involved fatalities. In the recreational boating realm, the primary target of preventive efforts is drownings. While serious injury accidents do occur, they do not make up as large a part of the accident picture as is the case in motor vehicle crashes; the fatality to reported injury ratio for boats is almost 14 times that of motor vehicles. Also as noted earlier, future analyses could increase the reliability of estimation for low frequency errors by combining two or more year's fatal accident data. For the past several years, the number of boating fatalities reported annually has run between 700 and 900. Three year's worth of data would increase the total to over 2,000 accidents, allowing better

detection of the less frequent errors. If the type of analysis explored here were to applied to a larger data base, more of the errors appearing in the Figure III .C.1 code list might be expected to show up in the list of those leading to fatalities. The fact that a particular error is associated with a relatively small number of deaths doesn't mean it is not a legitimate object of concern. Indeed, since many of the more common and well-known errors have been the target of boating safety efforts for some time, the less frequent errors may offer more potential as targets of preventive efforts. Aggregating accidents over three to five year periods would permit better identification of low frequency errors, yet still allow enough data points over time to permit identification of trends.

While the relative numbers of reported non-fatal injury accidents in boats is less than that of motor vehicles, the absolute number is considerably higher than fatalities, averaging three to four thousand per year. One year's worth of data should be quite ample to reveal errors leading to injuries on boats. In the present demonstration, the two types of accidents were combined. However, they are qualitatively different; fatalities often involve drownings and non-fatal injuries do not. It is very likely that the two types of accidents also involve different types of errors. Therefore, future analyses would be expected to examine them separately.

Accidents resulting only in property damage make almost half of reported accidents. The loss associated with these accidents is entirely economic and, even in dollar terms, considerably less costly than fatal and injury accidents. Moreover, the great majority of property damage accidents go unreported except to insurance carriers. Devoting half of available resources to what would amount to but a partial analysis of the least consequential accidents would be questionable practice. Property-damage-only could be omitted from the analysis of boater errors, at least until a system for identifying the more serious errors has been well established.

In the present demonstration, accident-producing errors were classified only by type of boat. However, like other entries in the BARD file, errors can be classified by any other data element appearing in the file, such as State, type of waterway, time of day, weather conditions and so on. They can also be classified by combinations of elements. However, as errors are subdivided by combinations of variables, the number of cases in each category rapidly shrinks. This loss of numbers underscores the need for large samples to begin with.

1.b. *Responsibility for Analysis*

The analysis performed in the present study was carried out by two highly experienced boaters. However, their task also included developing the classification system by which behaviors were coded. Application of the system in the future could be placed in the hands of those currently responsible for preparing the BARD file. With the codes well defined, the process of coding would not be difficult. It will, however, be somewhat time-consuming at first. The code list appearing in Figure III.C.1 will look a bit intimidating and it will take some time to become familiar with it. However, BARD analysts coding errors on a daily basis would soon be able to

navigate through it and find the appropriate codes quickly. The most time consuming aspect of the process is identifying the errors in the first place. This part of the task is already carried out by analysts as they process the original investigators' reports from the BAR and synthesize the narratives they enter into the BARD. Within a short time, the additional step of entering codes to identify errors would be a minor part of the BARD data entry.

Some instruction and practice will be needed in enabling analysts to interpret error codes uniformly. As objectively as the errors may be defined, there is always a need for judgement. Moreover, the narratives prepared by investigating officers are not always complete. Some go into considerable detail as to the specific errors that occurred; others leave a lot for analysts to infer from the objective information that is provided. Some investigators devote much of the narrative to describing characteristics of the accident already appearing elsewhere in the BAR, e.g. time of day, type of boat, weather, and provide little description of the actions leading up to accidents. However, the analysts who currently enter the BARD data have shown an ability to extract the most important elements of boat behavior from the BAR narratives and should be able to enter codes correctly with a modicum of instruction.

While the success of the error coding process lies primarily in the hands of those responsible for the BARD data entry process, the quality of information entered depends upon completeness and accuracy of the information provided in the BARs, prepared by investigating officers. The highly variable nature of current narratives evidences the need to seek improvement in their preparation. Some guidance given to investigating officers in the preparation of narratives would enhance their value in identifying boater errors.

2. *Next Steps*

The system of coding boater errors could be implemented immediately simply by adding the codes to the BARD instructional material, and providing space for up to three four-digit codes in the BARD data entry format. However, there are at least three reasons why this would not be a good idea.

First, the coding system described in this report is purely experimental; it has not yet been applied to the total BARD for even one year, let alone two or more years combined. Full scale application is very likely to reveal the need for modification, one of which is likely to be altering the codes to add some for errors not anticipated and deleting those that fail to show up even in a large data base. The coding process needs to be tested, and difficulties ironed out, before responsibility for its use is transferred to the community responsible for BARD preparation.

Second, it would not be beneficial to call for changes in the BARD system every time room for improvement is discovered. To do so would introduce a degree of turbulence that would be difficult for either the developers or users of the BARD to bear. Rather, changes need to be aggregated over time and introduced at periodic intervals.

Finally, it seems unlikely that the various parties involved in preparing the annual BARD file will initially welcome the task of describing and coding boater errors. The first task in gaining acceptance of this process will be convincing everyone that the information it provides is worth the effort involved. Accomplishing this task will require providing evidence that the product of the effort is worthwhile, evidence in the form of a data showing how users can exploit the existing data file to see what types of human errors are associated with various aspects of boating.

For these three reasons, it would seem prudent for the USCG to sponsor a full analysis of the 1996, 1997, and 1998 BARD file, and present the results to the boating safety community. The activity could be carried out under a small grant to a group by the boating safety community. To be useful, an oversight committee could be formed within the National Association of Boating Law Administrators (NASBLA), whose constituency is currently responsible for preparing the BARD files. The USCG could assist in the instruction of accident investigators and analysts to assure the quality of the analytic process. Instruction would ultimately go beyond just the coding of human errors to methods of analyzing data for planning and evaluation purposes. The process would be very similar to that employed by the National Highway Traffic Safety Administration in the early 80s to enable state highways safety offices to analyze their accident files to identify the traffic accident problems that were most prevalent in their states.

G. Summary

While human error underlies the great majority of boating accidents there has been no formal process for identifying the involvement of various errors in boating fatalities, injuries and property damage. While the Accident data maintained by the Boating Accident Report Database (BARD) contains narrative descriptions that are acceptably descriptive of errors leading to boating accidents, the information needs to be capable of electronic manipulation to be of use in the planning and evaluation of efforts to overcome those errors. A coding scheme was developed, through analysis of recreational boating behaviors capable of leading to damage, injury or death if not performed correctly. Approximately 300 specific behavior codes made up the system.

To test the utility of the system, a sample of 1,000 accidents from the 1997 BARD file was coded and the frequency with which each error occurred tabulated by type of boat. Through an iterative process, the system was progressively altered to yield a workable coding system , which was then used to tabulate the frequency of various errors by boat type. The purpose of the analysis was solely to test and demonstrate the coding system; the size of the sample employed was insufficient to lead to reliable estimates of actual accident frequency. However, the quantification of dangerous errors appears to provide information that could be of use in prioritizing boating safety efforts as well as in evaluating the results of those efforts over time. The following steps are suggested:

1. Apply the coding system to all fatal and injury accidents in the 1996 - 1998 BARD.

2. Assess the value of the data in planning and evaluating boating safety efforts.

3. If the assessment is favorable, transfer the error coding responsibility to the State analysts currently entering BARD data by demonstrating the value of the information to States, preparing materials and aiding investigating officers and BARD analysts, and sponsoring programs to aid state personnel in use of human error data for safety planning and valuation efforts.

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Chapter IV: A Framework for Undertaking RBS Policy Analysis

The next two chapters consider applications of selected risk management approaches to questions of concern to boating safety. On one level, we have examined boating safety risk management as a foundational attitude and approach: a persistent, overarching concern for intelligently determining and doing what most improves the safety of boaters (within a set of constraints), in the overall boating safety program and its individual aspects. We have reviewed some techniques for systematizing that concern and have delved into the issue of human-error accident causes. In this chapter, we develop a general framework for assessing safety policy decisions, a process for evaluating the best way of dealing with a given safety challenge. (Chapter V will go on to discuss some particular tools and applications of interest to boating safety risk management.)

A. Stages of Analysis

Here are a set of steps that are useful in undertaking policy analysis for boating safety or any other problem where there are a number of different potential alternatives and key interested parties :

- Define the Problem
- Specify Key Interested Parties
- Identify Alternative Options
- Analyze Ways Individuals Collect Information
- Determine Decision Processes of Stakeholders
- Specify Relevant Attributes
- Valuation of Attributes
- Evaluation of Alternatives

We will now illustrate each of these steps with some illustrations from the boating safety problem.

1. *Define the Problem*

Most research on decision making focuses on how problems are solved. However, if one has not solved the relevant problem, then the most elegant solution is of no practical value and may, in fact, compound the actual problem if translated into action. This is what is known as a Type III error (i.e. asking the wrong question). The following aspects need to be considered in examining

recreational boating accident causes and experience. A more detailed discussion of the problem finding process can be found in Kleindorfer, Kunreuther and Schoemaker (1993) (Chap. 2).

What are the objectives of the study? In the case of this study it appears to be to understand the nature of the boating accidents so that one can develop appropriate policy interventions for reducing future accidents.

Why is this an important problem for study? One needs to provide a rationale for why one wants to investigate this particular question and what is likely to emerge from such a study. In other words, the readers of this report need to be convinced that the problem of improving boating safety is important to study.

What hypotheses are being tested? One needs to examine a set of specific hypotheses and why they are important for the problem at hand. What would one do differently if an hypothesis is confirmed or disconfirmed? By addressing this question at the outset one is in a position to determine what data needs to be collected and analyzed. In constructing and testing hypotheses one has to be concerned with issues of correlation and causality. The fact that two variables are positively correlated does not necessarily imply causality. For example, the percentage of the population who graduates from college over the past 50 years and the number of boating accidents during this 50 year period probably has a very high positive correlation (i.e. both have increased). However, one cannot infer that an increase in education implies an increase in the chances of a boating accident.

How can one test the hypotheses with the data? One needs to have a clear understanding of how accurate the data are for testing specific hypotheses. How easy is it to obtain the data and how will these data be used? By indicating what data are easily available, how time-consuming it is to collect other data and what data are currently not available, one will go a long way to bounding the problem. If it is too difficult to obtain certain information for testing a specific hypotheses, one needs to recognize this at the outset and focus on questions that can be answered with sufficient accuracy that they will be useful for policy.

2. ***Specify Key Interested Parties***

It is important to specify all the important stakeholders who are concerned about the problem at hand. To determine which individuals or groups have standing, it is necessary to decide at what level the analysis should be undertaken. If the project is evaluated at the level of a specific state (e.g. California), then only residents in this state are considered. If, on the other hand, one is viewing the problem from a national perspective (e.g. the United States), then the costs and benefits of the citizens of the entire country will be incorporated in the analysis.

Each of the parties has their own agenda and a set of values which reflect their concerns. Frequently these values and concerns lead to conflicts between the different interested parties.

To defend their positions each of the stakeholders is likely to use their favorite experts to defend their position, focusing on issues of risk as a common element if the issue is one of health or safety of a given population. Often the experts differ between themselves on their estimates of the risk To the extent that data on probabilities and outcomes are available, this may help settle these differences. For many low probability events there may not be sufficient information to draw statistically valid conclusions from the existing data base. This needs to be made clear in any analyses that follow.

3. *Identify Alternative Options*

One needs to specify the alternative options that are being considered. One of these is frequently the *status quo.* This is a critical option since there are often very large costs associated with change. Furthermore the status quo is often the reference point for evaluating how well other alternatives perform. If there is sufficient political dissatisfaction with all of the other options and/or high transaction costs associated with changing from the status quo, then the current program will be maintained.

It is useful to identify as many specific alternatives as possible to deal with the problem at hand using as many key interested parties as feasible. There are a number of different ways that one can generate alternatives in a somewhat systematic fashion

Link Option to Objectives It is important to consider the main objectives of the problem and determine what alternatives are likely to meet these objectives. By being explicit with respect to these objectives one is more likely to be able to create a set of relevant alternatives than if one just tries to consider options in a vacuum.

Scenario Construction One important way of generating alternatives and a technique that we will be illustrating in more detail below is the construction of scenarios or use cases that characterize those elements of the problem that are viewed as critical to the problem at hand. More specifically a scenario characterizes a set of specific events which indicate what can happen if an accident occurs as well as ways of preventing certain events from occurring. Each scenario may suggest a set of alternatives for avoiding the particular situation.

Brainstorming In this approach individuals in a group setting suggest a set of options for consideration without by criticized by others as to their feasibility. One might begin this process by asking "Wouldn't it be nice if...?" or "Wouldn't it be awful if....?".

Other Approaches Some other approaches that are helpful in collecting information are reading earlier reports, the use of suggestion boxes, the Delphi approach, and providing feedback to all participants based on specific suggestions. More formally one can develop group decision support systems to aid the situation.

4. *Analyze Ways Individuals Collect Information*

There are very high costs of collecting accurate data on any specific problem which is one reason why there is a tendency to maintain the status quo (Samuelson and Zeckhauser 1988). It is important to clearly understand what type of data an individual is likely to collect for the specific problem at hand and how costly it will be for him or her to obtain this information. There may be opportunities to provide assistance to people in getting certain data or presenting it in an attractive and easily accessible form. The scarce resource for people today is attention and time rather than data, and we need to be aware of this should we pose solutions that require a large amount of data collection and analysis by the affected individuals.

5. *Determine Decision Processes of Stakeholders*

It is important for us to understand how individuals are likely to behave when dealing with problems which involve risk and uncertainty. One particularly challenging question is how to deal with the issue of *moral hazard.* By moral hazard we mean behaving in a riskier fashion because the affected individuals feel that they are better protected than they were in the past. In the context of a boating example, if operators believe that their boats are designed more safely than in the past, they may behave more recklessly on the water than in the past. This may actually create more accidents simply because the individuals have overcompensated in their reaction to the safer vehicle.

Another common decision process is the tendency to feel "it will not happen to me". Such a decision rule can be easily understood when we recognize that all of us make hundreds of choices each day and want some type of rule of thumb that enables us to eliminate taking certain actions. By acting as if an accident will not happen to me, the person does not have to think about the consequences of the event and determine what types of protective measures they will adopt.

More generally, by understanding the decision processes of individuals and groups (i.e. their probability biases and simplified decision rules) we can design strategies that are likely to achieve the desired set of objectives. (See Kahneman, Slovic and Tversky (1984) for a set of readings on probability biases and Kahneman and Tversky (1989) for a descriptive theory of choice under uncertainty). Furthermore, it will often be necessary to combine a set of different alternatives which reflect ways to deal with the behavior of individuals. For example, given the moral hazard problem one strategy for reducing boating accidents may be to design safer vehicles while at the same time impose restrictions on people's actions such as a well-enforced speed limit.

6. *Specify Relevant Attributes*

One of the key steps in developing a strategy for dealing with a particular problem is to specifying the relevant attributes that are important to at least one of the key interested parties. One needs to detail the benefits and costs (broadly defined) that need to be considered. Some of these attributes will be easily quantifiable such as the costs of installing certain safety features in a boat. Other attributes are more qualitative in nature such as the environmental impact of certain alternatives. Other attributes, such as the impact of specific alternatives on fear, dread , joy, happiness or other emotions, may be important elements of the problem. Value tree analysis is a promising approach for eliciting the various attributes of the key interested parties and combining them in a systematic fashion. (Von Winterfeldt 1987).

If there is uncertainty associated with the analysis then one has to assign probabilities to the different states of nature (e.g. accident, no accident) and the resulting outcomes to the relevant stakeholders if this state of nature actually occurs. If the alternative involves multiple time periods then one has to specify the outcomes that occur in each of these future periods and use a social discount rate to convert these benefits and costs to present value.

7. *Valuation of Attributes*

Once the attributes have been specified then one needs to quantify these impacts and attach some dollar or utility value to them for each of the affected individuals using techniques such as multi-attribute utility analysis. (See Keeney and Raiffa 1976). Sometimes these values can be determined directly, such as the cost associated with constructing a project. Other valuation procedures are more controversial, such as valuing a human life. (See Viscusi (1993) for a discussion of these issues). With respect to qualitative measures, such as environmental impact, economists have utilized contingent valuation procedures to elicit an individuals' "willingness to pay" (WTP) for changes in the quantity and quality of goods.

The field of contingent valuation is fraught with problems in trying to determine willingness to pay for certain goods. There is an interesting paper on this issue by Diamond and Hausman (1994) which raises a number of points as to why one has to be cautious in relying on WTP values. See also the review article on contingent valuation by Baron (1997) For example:

> *Embedding* ----WTP for cleaning up 10 lakes or 1000 lakes. Many people give the same amount when they are asked how much they are willing to pay to clean up 10 lakes or 1000 lakes.
>
> *Framing,*---- Asking people questions in different ways and getting different WTP responses

Valuing non tradeable items--- forcing people to put values on items that they don't want to trade (e.g. wedding ring)

Situation-specific values---valuing lives may depend on situation (e.g. shooting a burglar or saving Jessica McClure in the well) (Identifiable vs. statistical lives)

Valuing non-market goods (e.g. odors)

8. ***Evaluation of Alternatives***

Once each of the attributes are evaluated, some type of weighting procedure indicating the relative importance of each attribute is required to aggregate these impacts so that one can approximate how each alternative will affect society as a whole. This is a difficult question since each of the interested parties is likely to have a different weighting scheme for the relative importance of each attribute in evaluating different alternatives.

Decision analysis (see von Winterfeldt and Edwards (1986) and cost-benefit analysis (see Boardman et al 1996) are two related approaches for evaluating different alternatives in a systematic fashion. Both techniques require one to specify a set of alternatives, elements of uncertainty associated with specific events (e.g. probability of a boating accident) and the consequences resulting from each of these specific events (e.g. number of lives lost, resulting damage, emotional impacts). Each of these consequences have to be evaluated in a systematic manner.

9. ***Designing a Strategy***

In designing a strategy for reducing losses from boating accidents one has to consider not only the benefits and costs but that there are two key questions that need to be addressed:

- Who should bear the costs of reducing losses from future boating accidents?
- Who should pay for the losses caused by boating accidents?

There are two criteria normally utilized in addressing these two questions: *efficiency* and *equity*. By *efficiency* we mean the allocation of economic resources to maximize social welfare. Social welfare is defined by the citizenry and thus may vary from one political entity to another. *Equity* refers to concerns with fairness and the distribution of resources. An equitable distribution of resources may require the special treatment of certain individuals or groups at the expense of others. One key question that needs to be addressed in this domain is how much weight should be given to each of the interested parties when designing a strategy.

B. Application to the Boating Safety Problem

In this section we will illustrate the framework outlined above to the boating safety problem. A more detailed discussion of how one can utilize decision analysis and multi-attribute utility analysis in evaluating different alternatives can be found in Mandex, Inc. and Decision Sciences Consortium, Inc. (1984). The analysis which follows extends these ideas to consider the challenges one faces if there are many interested parties rather than just one concerned with developing a strategy for boating safety.

1. *Specify the Problem*

How can we determine an appropriate strategy for reducing the likelihood and consequences of boating accidents. This requires us to understand the nature of causal relationships between the boat, the operator of the boat and the external environment. One also needs to consider the cultural, social, legal and regulatory environments which guides the problem.

2. *Specify Key Interested Parties*

There are a number of key interested parties that need to considered in dealing with this problem. A few are illustrated below:

- Passengers
- General Taxpayer
- Swimmers and Divers
- Fishermen
- People on Shore
- Operator of the Boat
- Sailboaters
- Boat Manufacturers
- Retail Stores Selling Boats and Accessories
- Insurers
- Local, State and Federal Agencies
- Coast Guard
- Others.

3. *Identify Alternative Options*

Examples of some of the many alternatives that might be considered for dealing with a boating safety problem include things such as:

Modifying Individual Actions

- Licensing Requirements
- Driver Education Requirements

Modifying the Environment

- Require Personal Flotation Devices on the Boat
- Regulations on Brightness of Lights
- Boating Speed Limits
- Better Enforcement of Regulations
- Change Liability Rules Regarding Responsibility for Accident Costs
- Buoys in Channel for Better Lighting and Traffic Control

Modifying the Boat

- Redesign of Boats to Reduce Probability of Falling Out of Boat
- Limit Boat Powering
- Require Propeller Guards on Boat

Through a series of scenarios or use cases we may be in a position to suggest other options and alternatives and their impact on the key interested parties for the problem under consideration. Then one may want to construct an Alternative/Stakeholder matrix which lists each of the alternatives as a row and each interested party as a column. The challenge for the analyst is to better understand the reaction of each of the stakeholders to each of the alternatives using the subsequent stages of analysis listed below.

4. *Analyze Ways Individuals Collect Information*

Each of the stakeholders or interested parties will collect information on the benefits and costs associated with the specific alternatives. These data will be used to evaluate differences between the interested parties with respect to how they view specific options and ways that one may want to combine alternatives to develop a meaningful strategy.

5. *Specify Decision Processes of Stakeholders*

Each of the interested parties may use different decision processes which impacts on the types of information they are interested in collecting. Consider the following illustrative example with respect to boat safety. The boat operator may not collect information on protective devices

because he feels that the chances of an accident are so small that it is not worth worrying about. For this reason alone, he or she will not collect data on the consequences which might result from an accident. A swimmer, on the other hand, may be very cognizant of the possibility of being impacted by a boat and overestimate the chances that they will be impacted by a boat. He or she may be very concerned with the consequences of such an event and hence feel strongly about the need for better protective mechanisms.

The decision processes are to some extent related to the goals and responsibilities of the different interested parties. If the US Coast Guard (USCG) has the responsibility of reducing the number of lives lost from boating accidents then it will want to systematically evaluate the impact that each alternative and perhaps a combination of alternatives will have on this goal or objective. The USCG will then evaluate in a systematic manner the benefits and costs associated with each option in relation to reducing the accident rate. A boat operator, who utilizes a decision process which ignores specific events (e.g. a boat accident) if the perceived probability (p) is below a prespecified level (p*) will behave in a very different manner. We will need to investigate these decision processes before evaluating the different alternatives

6. *Specify Relevant Attributes*

There are a number of key attributes associated with the boating safety problem. Some of them are:

Cost of specific measures (e.g. personal flotation devices)
Probability of accidents of different magnitudes with and without specific measures
Consequences resulting from these accidents with and without specific measures
Emotional Concerns (e.g. happiness, joy, fear, dread)
Environmental Impacts of different alternatives

The investment costs of specific measures (e.g. a personal flotation device, a propellor guard) are incurred at a specific time while the impacts accrue over the life of the boat. One needs to specify these streams of benefits and costs (broadly considered) over time and utilize an appropriate discount rate to convert them to present value.

7. *Valuation of Attributes*

The valuation process is a challenging one because it requires data on the impacts of each alternative on the different attributes, many of which cannot be quantified easily. For example, one attribute that will be important in boat safety is number of lives lost or injured with and without specific protective measures. One may first want to just indicate these figures without associating some value to them and show how a specific protective measure is likely to fare in reducing these impacts (e.g. number of boating injuries with and without a personal flotation device as part of standard boating equipment). If one wants to combine this attribute with others as part of a multiattribute utility analysis then one needs to quantify the disutility of a human injury to each concerned stakeholder. There are likely to be differences in the valuation process between different interested parties (e.g. a boat operator and a swimmer in waters where there are

motorboats). We will return to this issue in more detail when we examine the benefits and costs of alternative solutions to "struck by boat or propellor accidents" in Part II of this report.

Another important part of the valuation process of any multiattribute problem is the relative weights placed on different attributes. How important are the costs of a better safety design feature of a boat which reduces injuries relative to the safety impacts of having such a measure in place? Each stakeholder will weigh these tradeoffs differently. For example, the Coast Guard may place a higher weight on the safety component relative to the costs than a boat manufacturer or retailer would.

8. *Evaluation of Alternatives*

Differential weighting of the various impacts by each of the interested parties need to be considered in evaluating the different impacts. More specifically, each stakeholder will value each alternative differently by placing different weights on specific attributes depending on his or her agenda.

9. *Designing a Strategy*

This last phase of the analysis requires a detailed discussion on the weights which should be given to the different stakeholders concerned with boating safety as well as the synergy between different alternatives. As pointed out above there are both efficiency and equity considerations which will effect the way different strategies are viewed by the relevant interested parties.

C. Initial Chapter References

The references cited below apply to the foregoing parts A. and B. of Chapter IV:

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D. Identification of Promising Interventions for Boating Risk Management

Appendix E contains an extension of the foregoing discussion on the identification of promising interventions for boating risk management. It includes a discussion of the concept of "Use Cases" as a means of structuring a boating safety problem. It goes on to discuss ways of viewing the boating safety database (as a "relational database") as a means of identifying promising alternatives.

Chapter V: Boating Risk Analysis Tools and Program Applications

Here, we will review some computer analytic capabilities that support boating safety decision analysis. These relate to multiattribute utility modeling, decision tree modeling and influence diagraming. A brief survey identifies some products that are presently of use in the RBS Program. (A more extensive unpublished, informal letter report also resulted.)

Following this, we briefly extend our consideration to the potential for use of risk management outlook and techniques to guide the management of the Recreational Boating Safety Program. These uses include program definition, prioritization of Program activities and elements, planning and budgeting where the object is to obtain the greatest degree of risk reduction for a given investment, an application of cost-benefit analysis. Framing alternatives in this way also supports communication with the public and other levels of government.

A. Decision Analysis Software for Boating Risk Management

1. *The Needed Tools*

The purpose of this section is to describe the results of a canvassing of existing software products that show promise of being useful tools for policy studies pertaining to boating risk management. For such studies the perspective of decision analysis is most appropriate. In particular, support for two methodologies is required, and support for a third class of methodology is highly desirable. The required methodologies are:

a. multiattribute preference (utility) modeling

A multiattribute outcome is one that has several facets of value. For example, a boating accident outcome has associated with it a monetary cost (from several sources), pain and suffering by those involved (typically involving several attributes), and possibly loss of life (among other things). When multiattribute outcomes occur, it is necessary to model the various facets of value, so that tradeoffs can be made properly during the decision processes. Even though subjective judgments are required, careful quantitative modeling and analysis is called for, especially when policy making will be contested due to economic and other special interests.

b. decision tree modeling

Outcomes, whether multiattributed or not, are created through an interacting series of decisions and chance events. Modeling the interplay of decisions and chance events is done using decision trees. Once a problem is represented as a decision tree, decision analysis theory can be applied to

yield very useful information for decision making purposes. This methodological approach is well-grounded theoretically and is very widely accepted as the normative ideal.

The highly desired methodology is:

c. influence diagraming

Influence diagramming is a way of structuring the causal associations for a particular topic area. This structuring is useful for agreeing on a common understanding of a situation, and for suggesting where interventions might be made to obtain better outcomes. This structuring process, however it is done (with or without the influence diagramming technique), typically precedes decision analytic studies.

2. *A Brief Survey of Available Software* [40]

Our investigation found no single tool generally available that is fully satisfactory for all three methodologies. This report was done with limited time resources, and so may have missed important software. It is unlikely, however, that relatively inexpensive and well supported products exist that are greatly superior to the products here described.

Even though no single product answers to the three main requirements (above), the conclusion of this report is positive. We obtained three main findings in this regard:

First, the Coast Guard R&D Center has sponsored development of a useful tool, IRA (Integrated Risk Assessment), that in time may be very helpful in organizing and filtering data pertaining to boating risk assessment. In its present concept and implementation, IRA is aimed at assessing risks in Coast Guard operations. Reporting data are entered into the system, filtered and organized according to a framework/methodology supported by the software vendor. Expert judgment is added in order further to make sense of the data and make it useful to assessing Coast Guard operations. A numerical index is applied that allows a quantitative score to be generated for identifying the most important risk conditions in a given situation. That is the main output of this program. It is assumed that once these, entirely reasonable, diagnostics have been identified and brought to the attention of decision makers, appropriate action can be taken to ameliorate the risks.

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[40] A number of other software products were evaluated in this informal survey. The results are not published here, but were made available to the Coast Guard in the form of a letter report.

IRA appears to be a very sensible and useful "first cut" tool. For many purposes---including the purposes for which the program was intended---a first cut will be all that is necessary. We believe, however, that for public policy making, especially with strongly contending economic interests (as is the case with boating risk management), it will usually be necessary to produce detailed quantitative models that assess costs and benefits, and that take into account uncertainties, for various policy alternatives. IRA is not a tool for this sort of detailed analysis. It is, nonetheless, a very nice concept and could be usefully adapted for "first cut" studies in boating risk management. Thus, we find that while IRA is not "the solution" here, it should be used as part of a comprehensive approach. Detailed analyses could be built upon data organized within IRA. IRA could be used to identify a set of promising options.

The second main positive finding is that there is one commercial product, DATA from TreeAge Software, that does support all three methodologies. It is weakest, but acceptable, on multiattribute modeling, and it appears to be quite strong on decision trees and influence diagrams. If one product had to be chosen, this would clearly be it. Third, a combination of products will suffice for supporting policy studies in boating risk management. These products are as follows:

a. *multiattribute preference (utility) modeling*

Expert Choice, from Expert Choice, Inc., (http://www.expertchoice.com/), is by far the most well-established commercial tool for modeling multiattribute outcomes. It is supported by a considerable literature and training is readily available. Unfortunately, Expert Choice has not been integrated with decision tree software. This, however, is a fairly minor limitation. Expert Choice will provide single numbers (utility values) for multiattributed outcomes. These numbers can be used as outcome values in decision tree software packages.

b. *decision tree modeling*

Several apparently very good packages are commercially available. These include:

DATA from TreeAge software, Inc. (http://www.treeage.com)
DPL: Decision Analysis Software from ADA Decision Systems
(http://www.dpl.adainc.com/)
Decision Explorer from Banxia Software (http://www.banxia.com/)

c. *influence diagramming*

Several apparently very good packages are commercially available. These are often integrated with decision treesoftware. They include:

DATA from TreeAge software, Inc. (http://www.treeage.com)
DPL: Decision Analysis Software from ADA Decision Systems
(http://www.dpl.adainc.com/)

Given these findings, it would appear that working with DATA from TreeAge is the place to start, and if further power (or technical support and training) is needed for multiattribute modeling, then Expert Choice could be used to produce inputs for DATA. That, at least, is our recommendation.

Finally a note on the assumptions made in doing this study:

1) This was a quick review of various decision analysis software products to detemine whether they might be suitable for building and deploying decision analysis DSSs pertaining to boating risk management with the Coast Guard.

2) We did not attempt to determine whether the various products are robust and relatively bug-free. Nor did we attempt in any direct way to evaluate the companies offering the various products and whether they can be relied upon. Rather, this assessment is of available functionality in specific software products.

B. Other Applications to RBS Program Management

1. *Guiding a National Program*

As developed in Section II.A.2, the risk management concept provides a valid organizing principle for the *national boating safety program,* because of its inherent and consistent focus on the effects of proposed plans and actions on the safety of boaters, the theme that runs through the whole of the FBSA. This focus is a natural intellectual and motivational glue that can hold the activities of the many participants in the national program together. It has the potential for bridging the gaps of varying organizational and individual intent and producing the best practicable safety outcome. Within our system of values and government, it is a fitting means through which the Coast Guard can exercise effective leadership of the diverse groups influencing boating safety. The techniques of risk management that are discussed below in terms of the Coast Guard's internal Recreational Boating Safety Program can be extended to this broader multi-party national program.

2. ***Managing the Coast Guard Program***

2a. *Program Effectiveness Measures*

Risk *management* approaches can enhance the effectiveness of the Coast Guard's internal Recreational Boating Safety Program. A measure of this *Program effectiveness* would ultimately be tied to the abilities of Program activities to reduce the number and consequences of accidents and the costs[41] involved in doing so: getting the "greatest bang for the buck," having the *highest ratio of safety benefits* (e.g., lives saved) *to costs*. Some applications and benefits are listed below:

- providing the Program with a single motivating goal and philosophy
- providing, in concept, a single, consistent measure of success
- providing a means of evaluating specific Program actions
- providing a means of deciding among alternative Program actions
- providing a means of optimizing overall Program content
- providing a means of organizing Program components
- providing a means of allocating funds effectively
- providing a means of communicating the value of proposed actions
- providing the basis for involving others in the discussion
- providing consistency with broad Coast Guard planning requirements
- promoting the communication of direction to other Program components
- promoting communication of direction outside the Coast Guard
- promoting proper Program recognition in external funding decisions.

The impact of many of these is self-evident considering the bottom line of the approach being proposed: "What is the ultimate effect of [whatever is being considered] on the safety of boaters?" The answer is capable of being expressed quantitatively,[42] allowing comparisons. (It bears repeating that this approach also provides a common basis for action of the many stakeholders of the wider national boating safety program.)

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[41] The concept of "cost" can be broadened to deal with intangibles, all forms of "dis-benefit" being convertible, more or less well, into financial terms through stated *assumptions* that are open to debate. While these may sometimes involve unsatisfying constraints, as in monetizing the "value of a human life," *sensitivity analyses* performed on variations in the assumptions often indicate bracketing values where consensus is possible, making them useful in practical decision making. In this way, too, it is conceivable to combine not just monetary issues (like *life-time cost* or pro-rata cost of a proposed regulation), but also issues such as enhancement or diminishment of individual freedom (and other social constructs, such as environmental quality) into a single calculus that elicits *consensus* among stakeholders.

[42] Some cases of outcome (or benefit/cost) measurement are harder, or less certain, or more needful of development effort than others, but the potential for some kind of useful, practical comparison always exists. This potential exists because the approach appeals to a single standard.

b. *Prioritizing Program Changes: benefit/cost analysis*

Let us consider the limited[43] case of internal Program *prioritization* as an example. This can be viewed in terms of prioritizing possible Program *changes*, or, more fundamentally, of stable Program elements. The former works from a base of what is. The latter starts fresh and asks what is the best combination of things -- approaches and actions, elements of organization -- that we can design. (It is "*zero-based.*") This is a valuable thing to do, but we will choose just to look at *changes* in this example. (The changes could be Program increases, decreases or shifts. All represent opportunities to improve Program Effectiveness.) The question is: "What are the best things we can do, starting from the existing Program base?"

"Best" in this case is taken to mean most productive of boating safety, a measure is needed. There are a number of possibilities that could be considered for what can be called a *Measure of Effectiveness.* We should select one that is anchored in our "safety of the boater" objective, one that is measurable and one that we feel we have the technical ability to apply to the choices in question. "Annual fatalities prevented" is one possible measure. Another might be an integrated fatality/injury/property damage *monetized* measure. (Here a monetary value is somehow ascribed to deaths and injuries.[44]) Any proposed measure has its limitations, for instance, the yearly number of fatalities resulting from a fairly specific cause (like fires on boats caused by electrical faults) may be so small or uncertain as to make a measure like "annual fatalities prevented" not useful. On the other hand, it could be a useful measure for major accident categories like "drownings" or "collisions" or for the RBS Program as a whole. The requirements of the decision at hand determine what is an appropriate "measure." It must be appropriate to both the object(s) and subject of the decision: to what is being measured and to what use it will be put, i.e., the kind of decision being made.

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[43] The case of asking how one could use his resources to motivate the range of external stakeholders to the greatest combined result responds to the same principles, but is more complex. While theoretically reducible to definite answers, the models for doing so are beyond present practical development. (Consider the state of development of models of the economy.) At present, useful analysis often takes the form of *approximations,* rules of thumb, trial and error, forms of gaming and *simulation, analogy, classification* of solutions and *expert opinion*, the largely intuitive reflection of one who has observed or experienced the governing factors in the situation and "understands" their relationships. (There are *group* reflections of the "expert" concept, too, perhaps tending toward a collective wisdom. The well known *Delphi* process is an example. Here group members individually opine on a question, those who differ are polled as to their reasons, these are communicated to the group, whose members then reconsider their first response, repeating until there is a clear and reasoned consensus.)

[44] There are a number of developed approaches in the literature, e.g., valuing the remaining productive capacity of a life lost in monetary terms, valuing the diminished capacity caused by an injury, or the cost of treatment or the loss of income. All involve assumptions that limit their application. They can still produce interesting insights, particularly in the realm of *relative risks.*

Once a measure has been selected, various alternatives for action can be evaluated in terms of it. (These alternatives are assumed to be set before us, perhaps advanced by different proponents. Section IV.B refers to the systematic generation of alternatives.) Alternatives should be defined so that they are roughly comparable in some way, for example, all seek to serve the same purpose and are active over similar time scales. Indications of merit of the various alternatives will result from this evaluation, for example, "Alternative (A) -- say controlling some aspect of boat design -- can be expected, on average, to save 5 lives per year." The Alternatives can be ranked according to "lives saved per year." But, that ranking would not normally be sufficient to provide understanding as to "the best thing to do." In the typical evaluation strategy, that requires introduction of the notion of the "cost," resources consumed or advantages lost, in pursuing the alternative. This provides the opportunity of comparing the benefit gained ("X" lives saved on average per year) to the cost involved ("Y" dollars consumed). A "*figure of merit*" for that alternative results: "X/Y lives saved per year per dollar spent." These can be determined and compared over the range of alternatives being investigated to allow their *relative ranking*.

If the terms of comparison are right and the evaluation is done correctly, the answers will be right. The process, while simple in concept, is fraught with possibilities for major error, both technical and substantive. Are we considering alternatives in equivalent terms? Are they the "right" terms in view of the applicable values? What are those values? Have we ignored major effects or subtle "costs" that could be determinative over time? Have we considered all stakeholders' interests? Have we correctly anticipated future events? These are questions of real life and practical outcome. The technical analysis, which may be very difficult in itself, may be faultless, while the projected outcome is in substantial error, because of an erroneous or overlooked assumption. This is not damning of the process which is as sound as human logic and character can make it. One must employ these very useful tools with respect for potential faults in the particular processes one uses in arriving at conclusions. "Answers" that are intended to underlie meaningful decisions should be tested in relation to their *criticality*. There are a number of ways of doing that, ranging from formal *sensitivity analyses* of the variables and assumptions involved, to an individual concern for the rightness of outcomes -- "Does this really seem reasonable/right?"-- to opinions of knowledgeable individuals within the organization, external (e.g., *peer) reviewe*rs, group (e.g., stakeholder) reviews, and determinations by authoritative persons or processes.

c. *Planning, Budgeting, Organizing*

Completion of a process such as that described above will improve the Program leadership's ability to get the most safety benefit for stipulated changes in expenditure. This is valuable, though not the last word on the subject. While we have indicated that the analysis should attempt to consider all alternatives, costs and benefits, often, some will have remained outside the analysis. They may have been overlooked, they may reflect complexities beyond the ability of the analyst, assumptions may have been *imposed*, or there may be wider purposes that overwhelm the safety goal. To the extent that the Program is *free* to act to seek its goal, this kind

of analysis will prove useful. (As mentioned at the outset, there is also the alternative of a bottom-up analysis which could help reconstruct the Program to the best overall effect, not just on the margins. This kind of effort is more complex and may meet practical constraints (such as requirements to maintain elements of the ongoing Program), but offers high value as a "*vision*" of the state of the Program for which to strive over time. Its components would also have practical value in themselves, e.g., identifying the best approaches among major Program components, such as regulation or boater education.)

The linkages between this kind of approach and Program planning, budgeting and organization are apparent. The Program plan is composed of the activities judged by this process to deliver the greatest composite safety benefit for their cost. The budget reflects these plans.[45] This can be extended to rationalizing organizational structure, as was begun in the Coast Guard's FY 87-91 RBS "Operating Program Plan." (Please refer to Figure V.D.1) In this Program Plan, an overall goal for improvement of a measure of boating safety was set in the form: "... reduce the annual rate of fatal boating accidents to X per Y total number of boats by (a certain date.)" The necessary change in fatality experience was apportioned to major Program components, allowing further apportionment to their constituent activities. While this provided a logic structure for optimizing Program organization, the quantitative relationships between Program actions and their safety results were (and largely, remain) undeveloped. [46]

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[45] Related analytical approaches (such as "multivariate utility analysis") can be applied directly budget optimization, as well. (See Chapter 4 of the Mandex reference.)

[46] This further apportionment of the safety goal was not actually done in this first attempt at structuring for lack of sufficiently detailed analysis and information. It is likely that full analysis is not justifiable in terms of its complexity, expense and the variability of some parts. As a practical matter, this kind of analysis needs to be selective and complemented by other insights. The cost of analysis must be kept in balance with its utility in terms of the decisions it supports.

GOALS	PROGRAM ELEMENTS	FUNCTIONS
1. Improve boats and associated equipment to a level that will cause a 12% reduction in the fatality rate from 1981 to 1990.	A. Establish safety regulations and guidelines for boats and associated equipment.	(1) Review the need for additional standards and develop as necessary; assess current standards to assure that safety purposes are served with minimum public cost and regulatory burden. (2) Support the development of appropriate non-federal boat safety standards.
	B. Ensure that boats and associated equipment meet minimum safety standards.	(1) Identify and investigate safety related boat and equipment defects. (2) Test boat types and appropriate associated equipment suspected to be in non-compliance or to have potential safety related defects. (3) Analyze defect reports and monitor active defect campaigns. (4) Process manufacturer violations. (5) Ensure that imported boats meet applicable safety standards. (6) Examine new or significantly altered boat models before introduction into the marketplace in quantity. (7) Provide information to recreational boat manufacturers.
2. Coordinate activities to improve boaters' knowledge, abilities and attitudes to cause an 11% reduction in the fatality rate from 1981 to 1990.	A. Coordinate the National Boater Education Program.	(1) Establish and maintain an effective education standard for the National Boater Education Program. (2) Ensure that the states develop educational programs complying with the national standard. In each state, assure annual instruction by all sources (State, volunteer, Auxiliary) of a number of boaters equivalent to the number of new boat operators. Nationally, this involves the States directly educating 65% of these boaters. (3) Provide support to the Coast Guard Auxiliary to develop educational programs complying with national guidelines and to provide approved courses to a number of boaters equivalent to 15% of the annual number of new boat operators nationwide. (4) Conduct Coast Guard boating information activities (including mass media campaigns). (5) Ensure that other volunteer organizations develop educational programs complying with national guidelines and that they annually provide approved courses to a number of boaters equivalent to 20% of the number of new boat operators nationwide. (6) Provide other educational services through the Coast Guard Auxiliary, including courtesy marine examinations (CMES).
3. Support improvements to the boating environment to reduce the fatality rate by 10% from 1981 to 1990.	A. Coordinate and support national boating safety law enforcement.	(1) Promote and support effective and consistent state and Federal boating safety law enforcement programs. (2) Coordinate the training of Coast Guard and State enforcement personnel to assure basic competence and procedural consistency.
	B. Support the Coast Guard Auxiliary in its performance of Search and Rescue and other non-RBS missions.	(1) Provide administrative support to the Auxiliary to meet the requirements of other Coast Guard programs.
	C. Obtain, analyze and communicate information to improve the management of the National Boating Safety Program.	(1) Ensure that fatal recreational boating accidents are properly investigated. (2) Obtain information on recreational boating accidents to determine boating hazards, their causes and the effects of safety actions and other influences over time. (3) Obtain information on boating law compliance. (4) Analyze boating program needs, communicate the results and manage the program.
	D. Coordinate other elements of the National Boating Safety Program.	(1) Ensure that other State laws and regulations are consistent with Federal requirements and do not adversely affect interstate use of boats.
	E. Transfer Federal financial support to the states.	(1) Administer the boating financial assistance program to support other program elements.
	F. Ensure compliance with Federal boat numbering laws.	(1) Coordinate state numbering programs.

Figure V.D.1: EXAMPLE OF RBS PROGRAM STRUCTURE RELATED TO SAFETY GOAL (Source: FY 1987-1991 USCG RBS Operating Program Plan)

C. Relation to Accident Statistics

Risk Management for Boating Safety requires a focus on preventing boating accidents. This focus is maintained through observation and logical consideration. Observation is often anticodotal: One sees or hears reports of an accident. Observation draws the person to consider the accident's causes and possible means of correction. Observation can also be systematic: One receives reports of many boating accidents and can consider them in a composite way: "This cause leads to more harm than that, etc." Systematic observation recorded as *statistics* plays a key role in the kind of analyses we have been considering, indicating the extent of a problem and often allowing its characterization in terms of other variables, and , over time, gaging the effects of interventions. The national boating accident statistical program was introduced in Section II.C.1, which discussed boating accident categories, and in connection with human error accident causation in Chapter III. Our analyses will depend in good degree on the availability and quality of information summarized in the national statistical system, supplemented, when necessary by data gathered to investigate a particular problem, as by a limited, special survey of a particular accident type, cause or potential remedy.

D. Chapter References:

Barish, N. and Kaplan, S.; Economic Analysis For Engineering and Managerial Decision-Making; McGraw-Hill.

Mandex, Inc. and Decision Science Consortium (L. Greenberg et al.); Recreational Boating Safety: Analysis for Programmatic Decisions; in work performed for USCG Office of Research and Development (Report # CG-D-9-84) NTIS AD# ADA147661; 1984.

National Research Council; Understanding Risk: Informing Decisions in a Democratic Society; 1996.

National Research Council; Risk Assessment in the Federal Government: Managing the Process; 1983.

U.S. Coast Guard; "Recreational Boating Safety Operating Program Plan (FY87-91)"; USCGHQ (G-B); Internal document; 1984.

Various Software Products, Publications and Internet Sites.

Appendices

Appendix A

GENERAL ACCIDENT STRUCTURE[1] - Version 2.2

(Please refer to Section II.B of text.)

FOCAL SITUATION	EXTERIOR INFLUENCES AND INTERVENTIONS
PRIOR STATE	
PRE-DISPOSING ELEMENTS	(Basic Options within a Larger Setting)
	REGIONAL SETTING Social/Legal Physical/Material State of Available Knowledge
PERSONAL STATE Personal History Intelligence Knowledge Values Attitudes Skills/Abilities Health Wealth Relationships Others	
	MATERIAL ATTRIBUTES Boat Design Construction Material Workmanship Prior Use Condition Outfitting Other

[1] © 1998 Salutary Technology, Inc.

PRE-OPERATIONAL	(Choice of Specific Operating Parameters)
PLANNING Purpose Awareness People involved Location Timing Expected conditions Equipment Components Arrangements	
	INTENT (Actionable embodiment of personal characteristics and planning)
SETUP Boat Outfitting Personal gear Provisions Information Communication	
	ENVIRONMENT ATTRIBUTES Physical: -Weather -Water -Boundaries -Obstructions -Designed transit layout - Road/Track Other Actors: - Type - Number - Location/Distribution Other Characteristics Social/Legal Assessment

INITIAL OPERATION	(Begin Operation; Pre-hazard Onset)
<u>INITIATION</u> Movement to the Operating Environment Perception of Environment Assessment Final Preparations	
	<u>INITIAL INTERACTION</u> Environment Material Personal Social Types and Rates of Change
<u>CONDUCT</u> Acclimate to Steady-state Operation Establish Characteristics of Routine Response	

HAZARD DEVELOPMENT	(Perceptible, Actionable Onset of Hazard)
	PARTICULAR HAZARD INTRODUCED Characteristics: - type - extent - timing - uncertainty
PERCEIVE HAZARD Objectivity Comprehension Readiness to react: - knowledge - skill/ability - psychological - material	
	HAZARD SITUATION DEVELOPS Alternative paths Likelihood
EVALUATE HAZARD Continue to Observe Identify Values at Risk Likelihood Consequences Intensity	
	HAZARD SITUATION DEVELOPS
EVALUATE RESPONSE Continue to Observe Identify Alternatives Consider Feasibility Seek Advice Experiment Estimate Success Rate Choose Course of Action	
	HAZARD SITUATION DEVELOPS

ACT ON HAZARD Do not act Act to avoid Act to mitigate	
	HAZARD REALIZED (Yes/No)
ACCIDENT	(Accident Event Onset)
ACCIDENT SEQUENCE Initial event Automatic Consequences Immediate Actions Affecting Outcome Sequence of Subsequent Events Call for Help?	
	EXTERNAL INTERACTION Continued Environmental Stress Continued Inter-object/personal Stress Changes in Situation Boundaries
IMMEDIATE ACCIDENT OUTCOME Life Health Material Wealth Common-wealth Environmental Change	

POST-ACCIDENT	(Begin Potential Recovery)
POST-ACCIDENT ACTION Amelioration Self-rescue/Recovery	
	POST-ACCIDENT INTERVENTION Search Rescue Assistance Renewal
PERSONAL CHANGES Life Health Wealth Knowledge Skills/Abilities	
	EXTERIOR MATERIAL CHANGES Commonwealth ENVIRONMENTAL CHANGES Alter: enhance/degrade SOCIETAL CHANGES Other people/groups involved Knowledge Intentions/Outlooks Organizations Law Culture
FINAL STATE	(Changes Absorbed)

Appendix B

DEPARTMENT OF TRANSPORTATION U.S. COAST GUARD CG-3865 (Rev. 9/95)	**BOATING ACCIDENT REPORT** STATE ASSIGNED CASE NO._____	FORM APPROVED OMB NO. 2115-0010 EXPIRES 02/28/2000

THE OPERATOR/OWNER OF A VESSEL USED FOR RECREATIONAL PURPOSES IS REQUIRED TO FILE A REPORT IN WRITING WHENEVER AN ACCIDENT RESULTS IN: LOSS OF LIFE OR DISAPPEARANCE FROM A VESSEL; AN INJURY WHICH REQUIRES MEDICAL TREATMENT BEYOND FIRST AID; OR PROPERTY DAMAGE IN EXCESS OF $500 OR COMPLETE LOSS OF THE VESSEL. REPORTS IN DEATH AND INJURY CASES MUST BE SUBMITTED WITHIN 48 HOURS. REPORTS IN OTHER CASES MUST BE SUBMITTED WITHIN 10 DAYS. REPORTS MUST BE SUBMITTED TO THE REPORTING AUTHORITY IN THE STATE WHERE THE ACCIDENT OCCURRED. THIS FORM IS PROVIDED TO ASSIST THE OPERATOR IN FILING THE REQUIRED WRITTEN REPORT.

COMPLETE ALL BLOCKS (INDICATE THOSE NOT APPLICABLE BY "NA")

ACCIDENT DATA

DATE OF ACCIDENT	TIME AM PM	NAME OF BODY OF WATER	LOCATION (GIVE LOCATION PRECISELY)

NUMBER OF VESSELS INVOLVED	NEAREST CITY OR TOWN	COUNTY	STATE	ZIP CODE

WEATHER (CHECK ALL APPLICABLE)	WATER CONDITIONS	TEMPERATURE (ESTIMATE)	WIND	VISIBILITY
[ ] CLEAR [ ] RAIN [ ] CLOUDY [ ] SNOW [ ] FOG [ ] HAZY	[ ] CALM (WAVES LESS THAN 6") [ ] CHOPPY (WAVES 6" TO 2') [ ] ROUGH (WAVES 2' TO 6') [ ] VERY ROUGH (GREATER THAN 6') [ ] STRONG CURRENT	AIR_____°F WATER_____°F	[ ] NONE [ ] LIGHT (0-6 MPH) [ ] MODERATE (7-14 MPH) [ ] STRONG (15-25 MPH) [ ] STORM (OVER 25 MPH)	DAY NIGHT [ ] GOOD [ ] [ ] FAIR [ ] [ ] POOR [ ]

NAME OF OPERATOR	OPERATOR ADDRESS

OPERATOR TELEPHONE NUMBER ( )	DATE OF BIRTH MO DAY YR	OPERATOR'S EXPERIENCE	INSTRUCTION IN BOATING SAFETY
[ ] MALE [ ] FEMALE		[ ] NONE [ ] UNDER 100 HOURS [ ] ≥ 100 HOURS	[ ] STATE COURSE [ ] U.S. POWER SQUADRON [ ] USCG AUXILIARY [ ] AMERICAN RED CROSS [ ] NONE

NAME OF OWNER	OWNER ADDRESS

OWNER TELEPHONE NUMBER ( )	NUMBER OF PEOPLE ON BOARD	NUMBER OF PEOPLE BEING TOWED	RENTED BOAT?
			[ ] YES [ ] NO

BOAT NO. 1 (THIS VESSEL)

BOAT REGISTRATION OR DOCUMENTATION NUMBER	STATE	HULL IDENTIFICATION NUMBER	BOAT NAME

BOAT MANUFACTURER	LENGTH	MODEL	YEAR BUILT

TYPE OF BOAT	HULL MATERIAL	ENGINE	PROPULSION	PERSONAL FLOTATION DEVICES (PFDS): WAS BOAT ADEQUATELY EQUIPPED WITH COAST GUARD APPROVED PFDS?
[ ] OPEN MOTORBOAT [ ] CABIN MOTORBOAT [ ] AUXILIARY SAIL [ ] SAIL (ONLY) [ ] ROWBOAT [ ] CANOE/KAYAK [ ] PERSONAL WATERCRAFT [ ] PONTOON BOAT [ ] HOUSEBOAT [ ] OTHER (SPECIFY)	[ ] WOOD [ ] ALUMINUM [ ] STEEL [ ] FIBERGLASS [ ] RUBBER/VINYL/CANVAS [ ] RIGID HULL INFLATABLE [ ] OTHER (SPECIFY)	[ ] OUTBOARD [ ] INBOARD [ ] INBOARD-STERNDRIVE (I/O) [ ] AIRBOAT	[ ] PROPELLER [ ] WATER JET [ ] AIR THRUST [ ] MANUAL [ ] SAIL	[ ] YES [ ] NO WERE PFDS ACCESSIBLE? [ ] YES [ ] NO

FUEL	NUMBER OF ENGINES	FIRE EXTINGUISHERS
[ ] GASOLINE [ ] DIESEL [ ] ELECTRIC	TOTAL HORSEPOWER	ON BOARD? [ ] YES [ ] NO USED? [ ] YES [ ] NO

OPERATION AT TIME OF ACCIDENT (CHECK ALL APPLICABLE)	ACTIVITY AT TIME OF ACCIDENT (CHECK ANY IF APPLICABLE)	TYPE OF ACCIDENT	WHAT CONTRIBUTED TO ACCIDENT? (CHECK ALL APPLICABLE)
[ ] CRUISING [ ] CHANGING DIRECTION [ ] CHANGING SPEED [ ] DRIFTING [ ] TOWING [ ] BEING TOWED [ ] ROWING/PADDLING [ ] SAILING [ ] LAUNCHING [ ] DOCKING/UNDOCKING [ ] AT ANCHOR [ ] TIED TO DOCK/MOORED [ ] OTHER (SPECIFY)	[ ] FISHING [ ] TOURNAMENT [ ] HUNTING [ ] SWIMMING/DIVING [ ] MAKING REPAIRS [ ] WATERSKIING/TUBING/ETC. [ ] RACING [ ] WHITEWATER SPORTS [ ] FUELING [ ] STARTING ENGINE [ ] NON-RECREATIONAL [ ] OTHER (SPECIFY)	[ ] GROUNDING [ ] CAPSIZING [ ] FLOODING/SWAMPING [ ] SINKING [ ] FIRE OR EXPLOSION (FUEL) [ ] FIRE OR EXPLOSION (OTHER) [ ] SKIER MISHAP [ ] COLLISION WITH VESSEL [ ] COLLISION WITH FIXED OBJECT [ ] COLLISION WITH FLOATING OBJ. [ ] FALLS OVERBOARD [ ] FALLS IN BOAT [ ] STRUCK BY BOAT [ ] STRUCK BY MOTOR/PROPELLER [ ] STRUCK SUBMERGED OBJECT [ ] OTHER (SPECIFY)	[ ] WEATHER [ ] EXCESSIVE SPEED [ ] IMPROPER LOOKOUT [ ] RESTRICTED VISION [ ] OVERLOADING [ ] IMPROPER LOADING [ ] HAZARDOUS WATERS [ ] ALCOHOL USE [ ] DRUG USE [ ] HULL FAILURE [ ] MACHINERY FAILURE [ ] EQUIPMENT FAILURE [ ] OPERATOR INEXPERIENCE [ ] OPERATOR INATTENTION [ ] CONGESTED WATERS [ ] PASSENGER/SKIER BEHAVIOR [ ] DAM/LOCK [ ] OTHER (SPECIFY)

ESTIMATED SPEED			
[ ] NONE	[ ] UNDER 10 MPH	[ ] 10 - 20 MPH	[ ] 21 - 40 MPH
[ ] OVER 40 MPH			

[ ] HIT AND RUN

DECEASED (IF MORE THAN 2 FATALITIES, ATTACH ADDITIONAL FORMS)

NAME OF VICTIM		ADDRESS OF VICTIM	WAS PFD WORN? [ ] YES [ ] NO
DATE OF BIRTH	[ ] MALE [ ] FEMALE	DEATH CAUSED BY [ ] DROWNING [ ] OTHER	[ ] DISAPPEARANCE
NAME OF VICTIM		ADDRESS OF VICTIM	WAS PFD WORN? [ ] YES [ ] NO
DATE OF BIRTH	[ ] MALE [ ] FEMALE	DEATH CAUSED BY [ ] DROWNING [ ] OTHER	[ ] DISAPPEARANCE

INJURED (IF MORE THAN 2 INJURIES, ATTACH ADDITIONAL FORMS)

NAME OF VICTIM		ADDRESS OF VICTIM	
DATE OF BIRTH	MEDICAL TREATMENT BEYOND FIRST AID? [ ] YES [ ] NO ADMITTED TO HOSPITAL? [ ] YES [ ] NO		DESCRIBE INJURY

WAS PFD WORN? [ ] YES [ ] NO PRIOR TO ACCIDENT? [ ] YES [ ] NO AS A RESULT OF ACCIDENT? [ ] YES [ ] NO
WAS IT INFLATABLE? [ ] YES [ ] NO

NAME OF VICTIM		ADDRESS OF VICTIM	
DATE OF BIRTH	MEDICAL TREATMENT BEYOND FIRST AID? [ ] YES [ ] NO ADMITTED TO HOSPITAL? [ ] YES [ ] NO		DESCRIBE INJURY

WAS PFD WORN? [ ] YES [ ] NO PRIOR TO ACCIDENT? [ ] YES [ ] NO AS A RESULT OF ACCIDENT? [ ] YES [ ] NO
WAS IT INFLATABLE? [ ] YES [ ] NO

OTHER PEOPLE ABOARD THIS BOAT (IF MORE THAN 2 PEOPLE, ATTACH ADDITIONAL FORMS)

NAME		ADDRESS	
DATE OF BIRTH	WAS PFD WORN? [ ] YES [ ] NO PRIOR TO ACCIDENT? [ ] YES [ ] NO AS A RESULT OF ACCIDENT [ ] YES [ ] NO WAS IT INFLATABLE? [ ] YES [ ] NO		
NAME		ADDRESS	
DATE OF BIRTH	WAS PFD WORN? [ ] YES [ ] NO PRIOR TO ACCIDENT? [ ] YES [ ] NO AS A RESULT OF ACCIDENT [ ] YES [ ] NO WAS IT INFLATABLE? [ ] YES [ ] NO		

BOAT NO. 2 (IF MORE THAN 2 VESSELS, ATTACH ADDITIONALIDENTIFYING INFORMATION)

NAME OF OPERATOR	OPERATOR ADDRESS
OPERATOR TELEPHONE NUMBER ( )	BOAT REGISTRATION OR DOCUMENTATION NUMBER STATE
NAME OF OWNER	OWNER ADDRESS
OWNER TELEPHONE NUMBER ( )	

PROPERTY DAMAGE

ESTIMATED AMOUNT:	THIS BOAT AND CONTENTS: $	OTHER BOAT(S) AND CONTENTS: $	OTHER PROPERTY: $

DESCRIBE PROPERTY DAMAGED

WITNESSES NOT ON THIS VESSEL

NAME	ADDRESS	TELEPHONE NUMBER ( )
NAME	ADDRESS	TELEPHONE NUMBER ( )

PERSON COMPLETING REPORT

NAME	ADDRESS	TELEPHONE NUMBER ( )
SIGNATURE	QUALIFICATION [ ] OPERATOR [ ] OWNER [ ] INVESTIGATOR [ ] OTHER	DATE SUBMITTED

FOR AGENCY USE ONLY

CAUSES BASED ON (CHECK ONE): [ ]THIS REPORT [ ] INVESTIGATION [ ] INVESTIGATION AND THIS REPORT [ ] OTHER

NAME OF REVIEWING OFFICE	DATE RECEIVED	RECREATIONAL [ ] NON-REPORTABLE [ ] COMMERCIAL [ ]
PRIMARY CAUSE		SECONDARY CAUSE

NOTE: The BAR contains a third page (which is blank) for a narrative accident description.

Appendix C

BOATING ERROR CODES

This appendix provides descriptions of the behaviors making up the error codes listed in the text. As noted in the text, the behaviors are described in terms of what is required to help assure safety in recreational boating. Each error in the error analysis involves failure to carry out the behavior correctly.

1000 PREPARATION FOR BOATING

This series involves behaviors in preparing for use of the type of boat being operated --- for general use of the boat, not for a specific event, which falls under 2,000. It also includes preparatory activities that take place during a boating event, not directly involving its operation, e.g. fueling engines.

Behavior Code	*Behavior not appropriately performed*
1100 PFDs	Having PFD's aboard
1110 Number and type	Having the required number and type of PFDs
1120 Wearable	Having the required number of wearable PFDs
1130 Throwable	Having the required number of throwable PFDs
1140 Reflective material	Having PFDs with reflective material for night use.
1150 Whistles and lights	Having PFDs with whistles and/or lights
1160 Serviceable	Having enough PFDs that are serviceable
1170 Inflation devices	Having inflation devices for inflatable PFDs
1180 Accessible	Having PFDs in a readily accessible location.
1200 Fire Safety	Making fire safety preparations,
1210 Extinguishers	Having fire extinguishers aboard
1211 Number and type	Having the right number and type for the vessel.
1212 Inspected	Assuring that the extinguishers have been inspected within the allotted time.
1213 Charged	Assuring that the extinguishers are fully charged.
1220 Stoves	Safe design, operation and maintenance of stoves
1221 Filling	Filling stoves properly.
1222 Design	Assuring that the stove design is conducive to safe use.
1223 Fuel storage	Assuring that stove fuel is safely stored.
1224 Distribution	Assuring the safe distribution of fuel from storage to stove.
1225 Fuel handling	Handling stove fuel safely.

1230 Engine fuel	Safe use of engine fuel .
1231 Storage	Assuring the safe storage of engine fuel.
1232 Distribution	Assuring the safe distribution of fuel from tank to engine.
1233 Handling	Assuring the safe handling of fuel from source to boat and aboard the boat.
1240 Electrical (non OEM)	Assuring the safe design, use and maintenance of electrical devices and connections .
1241 Protection devices	Having suitable protective devices in working order.
1242 Wire sizing	Assuring that wire is properly sized for its load and use.
1243 Battery shorting	Having batteries secured and protected to prevent accidental shorting.
1250 Back flame arrester	Assuring that gasoline engines are properly equipped with black flame arresters
1260 Vapor removal system	Assuring that engine vapor removal systems are in working order .
1261 Safe installation	Assuring that the vapor removal system is available and installed properly.
1262 Operability	Assuring that the vapor removal system is in operating condition.
1300 Controls	Assuring that controls are in operating condition.
1400 Lights	Assuring required lights are available and in operating condition
1410 Navigation	Assuring that navigation lights are available and in operating condition (misc).
1411 Required types	Assuring that required navigation lights and configurations are available .
1412 Serviceability	Assuring that navigation lights are capable of being used.
1420 Flashlights, spotlights	Assuring the availability of working flashlights and/or spotlights.
1430 Anchor lights	Assuring that anchor lights are available and in operating condition
1500 Sound Equipment	Having required sound-producing equipment available.
1600 Safety Outfit	Assuring that the boat is outfitted with appropriate safety items
1610 Rails/lines	Having the boat equipped with appropriate grab rails, lifelines, toe-rails
1620 Throw line	Having floating lines that can be thrown
1630 MOB recovery	Having some form of Man-Overboard recovery
1640 Distress signals	Having the boat properly equipped with flares or other visible signals
1650 Radio	Being equipped with a radio capable of communicating distress.
1660 First aid kit	Having appropriate first aid items.
1670 Pumps/bailers	Having the boat equipped with means of quickly removing shipped water.
1680 Anchor	Having the boat equipped with anchors suitable to intended operating conditions.
1690 Paddle	Being equipped with paddles, oars, or other means of manual propulsion.
1700 Navigation	Being equipped with navigation equipment appropriate to intended use .
1710 Compass	Being equipped with a working, accurate compass.
1720 Depth device	Having the boat equipped with means of determining depth.

1800	Boat	Assuring that the structure of the boat itself is suitable to intended use .
1810	Watertight integrity	Assuring that it is free of serious leaks or other opportunities for entry of water.
1820	Flotation materials	Having installed materials/tanks to keep the boat afloat in a useful attitude.
1830	Gear	Assuring that gear is secured to prevent it interfering with normal boat operations.
1900	Operator	The operator is capable of operating the boat safely .
1910	Knowledge/Skill	The operator has the knowledge and skill required t operate the boat safely.
1920	Physical ability	The operator has the physical ability to operate the boat safely.

2000 PREPARING FOR OPERATION

This series involves behaviors that are required in preparing the boat for safe operation on a specific occasion.

Behavior Code		*Behavior not appropriately performed*
2100	Crew	Assuring that the crew is suitable to the intended operation
2110	Assuring Abilities	Assuring that the crew possesses the physical ability for the intended operation
2120	Assuring Skill	Assuring that the crew possesses the skill needed for the intended operation
2130	Drills	Conducting drills prior to operation .
2131	MOB	Conducting man-overboard drills where appropriate (larger boats).
2132	Fire	Conducting fire drills where appropriate (e.g. engines, stoves).
2133	Capsize	Conducting capsize drills where appropriate (e.g. small boats).
2200	Needed Charts	Having the charts needed to navigate the intended route.
2300	Route Checks	Checking the intended route for possible safety hazards .
2310	Depths	Checking the intended route for adequacy of water depth.
2320	Surface obstructions	Checking the intended route for possible surface obstructions (e.g. docks).
2330	Underwater obstruct.	Checking the intended route for possible underwater obstructions (e.g. rocks).
2340	Waterfalls/dams	Checking the intended route for waterfalls and dams.
2350	Electric wires	Checking the intended route for overhead wires or underwater cables.
2360	Other hazards	Checking the intended route for other specific hazards (e.g. local knowledge)
2370	Fast current	Checking the intended route for locations of hazardous currents, (e.g. rapids)
2400	Weather Check	Checking the suitability of weather to the intended use, boat, and crew
2410	Current weather	Checking the suitability of the weather at the time operation begins
2420	Forecasts	Checking forecasts of weather during the intended use of the boat .
2421	Immediate	Checking forecasts for weather during the immediate leg of any trip.
2422	Long range	Checking forecasts for weather beyond the immediate leg.

2430	Current checks	Checking the intended route for the presence of strong/adverse currents
2431	Force	Checking the intended route for the force of any strong currents.
2432	Direction.	Checking the intended route for the direction of any strong currents.
2500	Special Equipment	Having available any special equipment appropriate to intended use .
2510	Exposure clothing	Having clothing appropriate to the elements, e.g. cold air or water.
2520	Restraints	Having harnesses, jacklines and/or other ways of restraining crew.
2530	EPIRB	Having an operational EPIRB for remote operation.
2540	Life raft	Carrying a life raft where appropriate to distance from shore.
2550	Survival suits	Having survival suits where conditions warrant.
2560	Storm gear	Having storm gear.
2570	Helmet	Bringing a helmet where conditions warrant (e.g. white water kayaking).
2600	Portable Communications	Having a means of communicating on boats not equipped with radio.
2700	Fuel	Assuring safe use of fuel .
2710	Fuel check	Checking fuel supply for adequacy to travel distance and fuel availability.
2720	Fueling	Safe fueling operations
2721	Engine off	Having the engine off during fueling.
2722	Close hatches	Closing hatches to prevent fuel vapor ingress
2723	No flames	Assuring absence of flame (e.g. candles, cigarettes, stove).
2800	Float Plan	Notifying responsible person of trip and alerting details
2810	What	Notifying others of intended activity, route, # persons, boat description, etc.
2820	When	Notifying others of estimated arrival and return times, when to seek help.
2830	Who	Notifying others of whom to notify at the agreed overdue time.
2900	Decision to Operate	Applying safety considerations to the decision to operate.
2910	Operator	Operators accurately considering their condition in deciding whether to operate,
2911	Physically able	Operators considering their physical ability to handle conditions.
2912	Necessary skills	Operators considering the adequacy of their skill/knowledge to conditions
2913	Health/fitness	Operators considering the adequacy of their health and fitness to conditions.
2920	Boat	Operators considering the boat in deciding whether to operate.
2921	Design	Considering the design of the boat relative to intended use.
2922	Condition	Considering the condition of the boat relative to intended use.
2930	Weather	Operators considering the weather in deciding whether to operate.
2940	Destination (location)	Operators considering the intended destination in deciding whether to operate.
2941	Navigability	Considering the ability of the waters to be safely navigated.

2942 Boat/Equipment	Considering the ability of the boat and its equipment to reach the destination.
2943 Crew	Considering the ability of the crew to operate through to the destination.

3000 SAFE OPERATION

This series involves behaviors that are required in operating the boat safely.

Behavior Code	*Behavior not appropriately performed*
3100 Boarding/Launching	Safely getting into a boat.
3110 Weight	Adjusting boarding to the weight of passengers to avoid swamping small boats.
3111 Amount	Limiting the total weight of passengers.
3112 Distribution	Distributing the weight of occupants to achieve balance.
3120 Entry	Steps for safe entry into boats.
3121 Procedure	Following safe procedures for entering boats.
3122 Handholds	Use of handrails and other handholds to prevent falls when entering boats.
3123 Sequence	Sequencing the entry of occupants to boats for balance and unobstructed access.
3200 Basic Control	Behavior involved in controlling the movement of boats.
3210 Starting	Steps in starting the engine.
3211 Transmission	Assuring that the transmission is in neutral to avoid abrupt motion.
3212 Blower	Running the blower sufficiently before attempting to start the engine.
3213 Sniff bilge	Sniffing the bilge for presence of fuel vapors before starting the engine.
3220 Motion control	Maintaining control of the boat within safe limits of boat and crew.
3221 Direction	Controlling the turning motion (yaw) of the boat in a safe manner..
3222 Speed	Controlling the straight line (linear) speed of the boat through the water.
3223 Thrust for steering	Controlling the thrust where needed for steering force (e.g. jet power).
3224 Acceleration	Controlling the rate of change in speed (increase/decrease).
3300 Safety Practices	Following safe practices when maneuvering the boat subject to external limitations
3310 Speed	Adjusting speed to external limitations.
3311 Posted limit	Adjusting speed to limits imposed by law.
3312 Boat characteristics	Adjusting speed to limits imposed by characteristics if the boat.
3313 Congestion	Adjusting speed to limits imposed by the number of boats in the vicinity.
3314 Near boats	Adjusting speed to limits imposed by the proximity of other boats.
3315 In waves / wakes	Adjusting speed to limits imposed by operation in waves or wakes.

	3316 For maneuver	Adjusting speed to limits imposed by the nature of maneuvers to be performed.
	3317 Near land	Adjusting speed to limits imposed by the proximity of land.
	3318 Near swimmers	Adjusting speed to limits imposed by the proximity of swimmers.
3320	Turning	Adjusting rate of turn as dictated by external limitations.
	3321 Control	Adjusting the rate of turn in relation to various maneuver limitations
	3322 Congestion	Adjusting the rate of turn to limits imposed by proximity of other boats.
	3323 Boat characteristics	Adjusting the rate of turn to limits imposed by the characteristics of the boat.
3330	Lookout	Exercising proper lookout to ensure safe operation.
	3331 Looking ahead	Looking ahead to see obstructions to the intended path.
	3332 Before turning	Looking to the side and behind before starting a turn.
	3333 Around	Exercising 360-degree surveillance.
	3334 Vision obstructions	Overcoming vision obstructions to assure a clear view.
	3335 Small objects/PIW	Looking at the surface to detect small objects or people in the water.
	3336 Depth/position	Looking periodically to check position, depth, and correlation of the two.
3350	Chart Navigation	Using navigational charts to assure safe operation.
	3351 With observations	Correlating chart information with sight / sound / electronic / compass information.
	3352 Chart reading	Interpreting information presented on the chart.
	3353 Plot fix	Establishing precise location on a chart.
	3354 Determine course	Use of charts to determine safe course..
3360	Hazard recognition	Recognizing hazardous characteristics of boats, boaters, waterways, weather.
3370	Allowing Space	Allowing sufficient space around boat to adjust safely to danger that may appear.
	3371 From other boats	Allowing sufficient space from other boats
	3372 From structures	Allowing sufficient space from fixed structures, such as land and land structures, moored vessels, etc.
	3373 From swimmers	Allowing sufficient space from swimmers in the water.
3380	Constrained in current	Avoiding being trapped by current (pinned against object, caught in hydraulic, etc.)
3400	Rules of the Road	Adhering to rules of the road per se (where no other safe practice is involved)
3410	Collision risk	Deciding whether a risk of collision exists.
3420	Specific rules	Adhering to specific rules of the road.
3421	Overtaking	Adhering to rules governing overtaking other boats.
3422	Maneuverability rules	Adhering to rules for yielding to less maneuverable vessels (e.g. large ships, etc.)
3423	Arbitrary rules	Adhering to arbitrary rules for right of way (e.g. from right, starboard tack, etc.)

3430 General prudential	Adhering to rules requiring prudent operation in general.
3500 Lines	Employing safe practices in use of rope, chain, or wire.
3510 Securing end	Securing one end to the boat being operated.
3520 Body parts free	Keeping parts of the body free from being struck or entangled.
3530 Surges	Allowing for surges when securing lines
3540 Easing	Easing off on lines under the appropriate conditions without jamming / fouling.
3550 Knot tying	Tying knots that will avoid coming loose, or can be loosened when necessary.
3560 Staying clear	Staying clear of lines that are under great strain.
3600 Special Operations	Specific boating operations requiring special activities.
3610 Coming alongside	Coming alongside a dock or other vessel.
3611 Approach slowly	Approaching slowly enough to maneuver properly and avoid possible damage.
3612 Approach angle	Approaching at an angle that will bring boat alongside, without colliding..
3613 Low speed steering	Steering at low speed in a way that bring boat alongside, without colliding..
3614 Body parts clear	Keeping parts of the body clear of contact point to prevent injury.
3615 Jumping	Transferring from the boat to the dock or the other vessel.
3620 Anchoring	Anchoring in a way that avoids injury/damage in process or afterward.
3621 Ready anchor	Having a proper anchor ready to go for planned or emergency anchoring.
3622 By bow	Avoiding anchoring by the stern when danger of swamping or damage exists.
3623 Scope	Having sufficient scope to prevent dragging, but not to swing into other boats.
3630 Towing	Towing or being towed an a manner that will prevent injury or damage.
3640 Unplanned events	Maintaining basic safety of the boat while coping with unplanned events.
3650 Waterskiing	Carrying out waterskiing (tubing, etc.) activities in a safe manner.
3651 Locations	Choosing a location that is safe and legal.
3652 Regulation	Following local regulations for waterskiing.
3653 Obstructions	Operating in areas free of, and avoiding obstructions.
3654 Time of day	Operating during times of day when waterskiing is permitted (i.e. daylight).)
3656 Observation	Having a qualified observer, suitably situated, in addition to the operator.
3657 Conditions	Operating only under safe weather and water conditions.
3658 Operation	Operating the boat in, and skiing in a safe manner.
3659 Recovery	Maneuvering alongside and bringing the skier aboard in a safe manner.
3660 Wave jumping	Any activity in which a boat or skier deliberately jumps waves or wakes.
3670 Sailing	Behaviors specific to sailing that are required for safe operation.
3671 Weight distribution	Distributing weight appropriately relative to the wind direction and strength.

	3672 Shortening sail	Shortening sail when wind conditions warrant.
	3673 Spilling wind	Spilling the wind to avoid extreme heel or capsize.
	3674 Gybe control	Operating the boat and controlling sheets to prevent a damaging gybe.
3700	Operating at Night	Behaviors specific to night operation that are required for safe operation.
3710	Running lights	Behaviors involved in the proper use of running lights.
	3711 Configuration	Arranging the correct configuration for the occasion.
	3712 Operation	Activating the correct lights at the proper time.
3720	Interpreting others	Accurately interpreting running lights of other vessels to avoid collision.
3730	Anchor lights	Displaying anchor lights at the proper time.
3740	Avoid confusing displays	Avoiding confusing displays of lights, e.g. extra lights.
3750	Unlighted objects	Locating and/or detect unlighted objects in or approaching intended path.
3760	Lighted objects	Detecting and correctly identifying lighted objects.
3770	Adjust speed	Adjusting the boat's speed to limitations of night visibility.
3780	Illuminating self	Shining a light on the boat or sail to improve conspicuity when near others.
3800	Communicating	Giving information to others were necessary to prevent injury or damage.
3810	To Crew	Giving information to crew members orally or through signs.
3820	To other vessels	Giving information to operators or crew of other vessels
3821	Audible signals	Using whistles or horns of required intensity at appropriate times.,
3822	Radio	Using an available radio to contact other vessels or shore stations (e.g. USCG).
3823	Hails/hand signals	Hailing or giving hand signals to operators of other vessels.
3830	Other	Other means of communicating to crew, other vessels, or shore.

4000 OCCUPANT PROTECTION

This series involves behaviors that are required in protecting the boat's occupants from injury or death in the event of an extreme condition or accident.

Behavior Code	*Behavior not appropriately performed*
4100 Falls Overboard	Behaviors involved in preventing an occupant from falling overboard.
4110 Handhold/footing	Assuring a firm grip, or secure footing on the boat when conditions warrant.
4120 Inside cockpit/cabin	Remaining inside the cockpit in rough weather.
4130 Remain seated	Remaining seated when boat stability or conditions warrant.
4200 Wear PFD Under Risk	Wearing PFD under conditions that create significant risk of drowning.
4210 High risk of immersion	Wearing when conditions create significant risk of immersion (e.g. rough sea).
4220 Difficulty finding in water	Wearing when conditions would make it difficult to locate in water (e.g. night).
4230 Difficulty recovery	Wearing when it would be difficult to recover the person from the water.
4240 Unable to swim	Wearing by occupants unable to swim.
4250 Cold water	Wearing when cold water would jeopardize chances of remaining afloat.
4260 Unconscious	Wearing under conditions that might render the person unconscious.
4300 First Aid	Giving first aid to injured occupants.
4310 Sun/heat/hypothermia	Treating victims of extreme temperature or sun exposure.
4320 CPR	Giving cardio pulmonary resuscitation
4330 Other first aid	Giving other forms of first aid.
4340 Call for help	Issuing calls for help where it is needed.
4400 Voluntarily Entering Water	Taking steps to prevent injury by those voluntarily entering the water.
4410 Avoid strong currents	Avoiding entry where strong currents could sweep swimmer into danger.
4420 Swim upstream	Swimming upstream from boat so that current sweeps swimmers toward boat.
4430 Trail line	Trailing a line behind the boat in current to facilitate return from downstream.
4440 Facilitate egress	Providing ladders or other devices to facilitate egress from the water.
4450 Flotation	Using some form of flotation, where conditions or swimmer ability indicates.
4460 Swimming after boat	Avoiding attempts to swim after a lost boat.
4470 Stay clear of boat.	Staying clear of boats to prevent being struck / pinned (e.g. waves moving boat).
4500 Use of Alcohol	Avoiding use of alcohol in amounts, or under conditions that impose risk.
4510 Control own	Controlling one's own consumption of alcoholic beverages.
4520 Control others'	Controlling the consumption of alcohol by other occupants.
4530 Recognizing signs	Recognizing the signs of alcohol impairment in others.
4540 Protecting impaired	Protecting impaired occupants from the risk of injury or illness.

5000 ENVIRONMENTAL LIMITATIONS

Behaviors involved in dealing with limitations on safe boating created by the natural environment.

Behavior Code	*Behavior not appropriately performed*
5100 Rough Conditions	Behaviors involved in handling rough conditions
5110 Recognizing onset	Recognizing the occurrence of conditions that warrant action.
5120 Estimating duration	Estimating how long the conditions are likely to last.
5130 Responding	Responding to rough conditions when they occur.
5131 Wearing PFDs	Assuring that PFDs are worn.
5132 Seeking shelter	Seeking protected anchorage / mooring or a lee from rough conditions.
5133 Securing vessel	Assuring vessel is buttoned up, gear restrained, pumps / bailers readied.
5134 Adjusting speed	Adjusting the speed of the boat to wind and water conditions.
5135 Adjusting direction	Adjusting the direction of the boat to wind and water conditions
5136 Balancing boat	Balancing the boat to prevent excessive roll or pitch in rough conditions.
5137 Bailing/pumping	Removing water in the most effective and efficient manner.
5200 Limited Visibility	Behaviors involved in dealing with limited visibility.
5210 Avoid obstructed area	Avoiding areas where obstructions may be encountered (e.g. rocks, boats) or moving to area with improved visibility.
5220 Lights/sound signals	Showing lights and sounding fog signals to warn other of the boat's presence.
5230 Slow speed	Operating slowly enough to respond to dangers as they become visible.
5240 Listen (no engine)	Listening for sounds of boats or obstructions, turning off engine as needed.
5250 Avoid shipping channel	Staying out of channels frequented by large ships.
5260 Anchor and wait	Anchoring and waiting for visibility to improve.

6000 EMERGENCIES

Behaviors involved in responding to sudden events giving rise to potential danger,

Behavior Code	*Behavior not appropriately performed*
6100 Falls Overboard	Behaviors in response to accidental falls overboard.
6110 Pass the word	Quickly notifying others of a fall overboard.
6120 Throw device immediately	Quickly throwing a flotation device to the person in the water.
6130 Post lookout	Posting someone to observe and point to the person in the water.

6140	Stop/turn immediately	Stopping the vessel or beginning a turn back as soon as possible.
6150	Approach (power)	Maneuvering the vessel under power to a stop safely alongside the person in water.
6160	Approach (sail)	Maneuvering the vessel under sail to a stop safely alongside the person in water.
6170	Fix/radio call	Sending a radio call giving location of emergency.
6180	Hoisting victim	Preparing for and hoisting the person out of the water.
6200	Survival in Water	Behaviors involved in improving chances of survival in the water.
6210	Boat for flotation	Using the boat for flotation (e.g. capsized boat).
6220	Other objects	Using other objects to help remain afloat.
6230	Clothes for floatation	Using clothing to help remain afloat.
6240	Gaining conspicuity	Maximizing the size and contrast of the search object to potential rescuers.
6250	Conserving energy	Behaviors involved in conserving energy while afloat.
6260	Conserving heat	Behaviors involved in conserving heat and preventing hypothermia.
6270	Swim across current	Swimming across current to land rather than toward a specific point.
6280	Entanglement	Preventing and overcoming entanglement (e.g. rigging, weeds).
6300	Extinguishing Fires	Behaviors involved in extinguishing fires aboard.
6310	Use extinguisher	Using a portable fire extinguisher properly
6320	Water	Using water as an agent when appropriate, but not when it will spread fire.
6330	Eliminate sources	Eliminating the source of combustible material
6311	Fuel supply	Cutting off liquid and gas fuel supply (e.g. propane, alcohol)
6312	Electrical source	Cutting off electrical supply.
6400	Seeking Help	Seeking help in an emergency.
6410	Radio at first sign	Using the radio before the situation becomes a crisis..
6420	Distress signals	Using available means of signaling distress (visual and audible).
6430	Use of EPIRB	Using EPIRB when needed and to best advantage.

9 Not Classifiable

This series involves behaviors that cannot be classified

9100	Insufficient Information	The information in accident reports is insufficient to identify behaviors.
9200	Act of Nature	The accident resulted from an act of nature.

Appendix D

NUMBER AND PERCENT OF ERRORS BY BOAT TYPE

	Missing Other	Sail	Open Small	Open Power	Cabin Power	PWC	Total
1100 PFD Outfit			3	1			4
			1.0%	.1%			.2%
1110 Number and type			18	6			24
			6.1%	.8%			1.4%
1160 Serviceable		1	1				2
		1.5%	.3%		1		.1%
1180 Accessible		1			1%		2
		1.5%					.1%
1230 Engine fuel				2			2
				.3%			.1%
1232 Distribution				1			1
				.1%			.1%
1240 Electrical --non OEM		1		1	1		3
		1.5%		.1%	1%		.2%
1300 Controls			1	12	1	2	16
			.3%	1.6%	1%	.4%	.9%
1420 Flashlights, spotlights				3	1		4
				.4%	1%		.2%
1610 Grab rails, lifelines, toe-rails		1		3	1	1	6
		1.5%		.4%	1%	.2%	.3%
1640 Distress signals				1			1
				.1%			.1%
1670 Pumps&bailers				4			4
				.5%			.2%
1800 Boat	1		2	3		1	7
	1.8%		.7%	.4%		.2%	.4%
1810 Watertight integrity		1	1	5			7
		1.5%	.3%	.7%			.4%
1820 Flotation materials			2	5			7
			.7%	.7%			.4%
1830 Gear stowage		1		5	2		8
		1.5%		.7%	2%		.5%
1910 Knowledge&Skill	1	4	6	5	2	38	56
	1.8%	5.9%	2.0%	.7%	2%	8.3%	3.2%

	Missing Other	Sail	Open Small	Open Power	Cabin Power	PWC	Total
1920 Physical ability						1	1
						.2%	.1%
2110 Assuring Physical abilities	1	1	2	1			5
	1.8%	1.5%	.7%	.1%			.3%
2120 Assuring Skill	2		1	2		16	21
	3.6%		.3%	.3%		3.5%	1.2%
2131 MOB		2		2			4
		2.9%		.3%			.2%
2133 Capsize		2					2
		2.9%					.1%
2300 Route Checks				2			2
				.3%			.1%
2310 Depths			1	2	1	1	5
			.3%	.3%	1%	.2%	.3%
2330 Underwater obstructions	1		1	9	1	4	16
	1.8%		.3%	1.2%	1%	.9%	.9%
2340 Waterfalls and dams			6	1			7
			2.0%	.1%			.4%
2360 Other hazards				3			4
				.4%			.2%
2370 Fast current	1			2			3
	1.8%			.3%			.2%
2400 Weather Check			2	1			3
			.7%	.1%			.2%
2410 Current weather					1		1
					1%		.1%
2420 Forecasts				1			1
				.1%			.1%
2500 Special Equipment	1					3	4
	1.8%					.7%	.2%
2510 Exposure clothing		1	3			3	7
		1.5%	1.0%			.7%	.4%
2570 Helmet			2				2
			.7%				.1%
2710 Fuel check				1			1
				.1%			.1%
2720 Fueling				1			1
				.1%			.1%
2723 No flames				2			2
				.3%			.1%
2800 Float Plan			1				1
			.3%				.1%

	Missing Other	Sail	Open Small	Open Power	Cabin Power	PWC	Total
2820 When				2			2
				.3%			.1%
2911 Physically able			1	6		2	9
			.3%	.8%		.4%	.5%
2912 Necessary skills			2	1		1	4
			.7%	.1%		.2%	.2%
2913 Health&fitness			1	3			4
			.3%	.4%			.2%
2921 Design			9	2			11
			3.1%	.3%			.6%
2922 Condition			2				2
			.7%				.1%
2930 Weather	1	1	6	4	1		13
	1.8%	1.5%	2.0%	.5%	1%		.7%
2940 Destination --location			1				1
			.3%				.1%
2941 Navigability		1	14	2		1	18
		1.5%	4.8%	.3%		.2%	1.0%
2942 Boat--Equipment			9	1		2	12
			3.1%	.1%		.4%	.7%
2943 Crew			1	1		2	4
			.3%	.1%		.4%	.2%
3100 Boarding&Launching			1				1
			.3%				.1%
3110 Weight	1			2	1		3
	1.8%			.3%	1%		.2%
3111 Amount			9	4	1		13
			3.1%	.5%	1%		.7%
3112 Distribution			1				1
			.3%				.1%
3130			1	1		1	4
			.3%	.1%		.2%	.2%
3131			2				3
			.7%				.2%
3133						1	1
						.2%	.1%
3210 Starting				1		3	4
				.1%	1	.7%	.2%
3211 Transmission				2	1%		2
				.3%			.1%
3213 Sniff bilge				1			2
				.1%			.1%

	Missing Other	Sail	Open Small	Open Power	Cabin Power	PWC	Total
3220 Motion control				2			2
				.3%			.1%
3221 Direction			3	12		14	29
			1.0%	1.6%		3.1%	1.7%
3222 Speed				3		1	4
				.4%		.2%	.2%
3223 Thrust for steering						12	12
						2.6%	.7%
3224 Acceleration	1			5	1	3	10
	1.8%			.7%	1%	.7%	.6%
3300 Safety Practices	1		2	1	1		5
	1.8%		.7%	.1%	1%		.3%
3310 Speed				7	1	5	13
				.9%	1%	1.1%	.7%
3311 Posted limit				1			1
				.1%			.1%
3312 Boat characteristics				2			2
				.3%			.1%
3313 Congestion				3		4	7
				.4%		.9%	.4%
3314 Near boats	2	2		6		30	40
	3.6%	2.9%		.8%		6.6%	2.3%
3315 In waves & wakes	2			20	2	28	52
	3.6%			2.6%	2%	6.1%	3.0%
3316 For maneuver				7		5	12
				.9%		1.1%	.7%
3317 Near land	1			6		3	10
	1.8%			.8%		.7%	.6%
3318 Near swimmers						1	1
						.2%	.1%
3320 Turning				1			1
				.1%			.1%
3321 Control	1			6	1	3	11
	1.8%			.8%	1%	.7%	.6%
3324						2	2
						.4%	.1%
3325				1			1
				.1%			.1%
3330 Lookout	1	1		10	3	15	30
	1.8%	1.5%		1.3%	3%	3.3%	1.7%
3331 Looking ahead	2	1		13	1	13	30
	3.6%	1.5%		1.7%	1%	2.9%	1.7%

	Missing Other	Sail	Open Small	Open Power	Cabin Power	PWC	Total
3332 Before turning	2			6		15	23
	3.6%			.8%		3.3%	1.3%
3333 Around	1			6	1	7	15
	1.8%			.8%	1%	1.5%	.9%
3334 Vision obstructions				4	2	7	13
				.5%	2%	1.5%	.7%
3335 Small objects&PIW				4		4	8
				.5%		.9%	.5%
3336 Depth&position	1		1	35	9	9	55
	1.8%		.3%	4.6%	8%	2.0%	3.2%
3354 Determine course		1			1		2
		1.5%			1%		.1%
3360 Hazard recognition			1	3			4
			.3%	.4%			.2%
3371 From other boats	6			15	1	77	99
	10.9%			2.0%	1%	16.9%	5.7%
3372 From structures	1			13	2	10	26
	1.8%			1.7%	2%	2.2%	1.5%
3373 From swimmers				1		2	3
				.1%		.4%	.2%
3380 Constrained in current		1	23	9			33
		1.5%	7.8%	1.2%			1.9%
3421 Overtaking				2		1	3
				.3%		.2%	.2%
3422 Maneuverability rules				2			2
				.3%			.1%
3423 Arbitrary rules	1			6	1	9	17
	1.8%			.8%	1%	2.0%	1.0%
3430 General prudential	1					4	5
	1.8%					.9%	.3%
3500 Lines					1		1
					1%		.1%
3510 Securing end							1
							.1%
3520 Body parts free	2	1	3	5		1	12
	3.6%	1.5%	1.0%	.7%		.2%	.7%
3560 Staying clear				2			2
				.3%			.1%
3610 Coming alongside	1			1		1	3
	1.8%			.1%		.2%	.2%
3611 Approaching slowly	1			1		3	5
	1.8%			.1%		.7%	.3%

	Missing Other	Sail	Open Small	Open Power	Cabin Power	PWC	Total
3614 Body parts clear				2		1	3
				.3%		.2%	.2%
3615 Jumping	1			1	2		4
	1.8%			.1%	2%		.2%
3620 Anchoring				1	1		2
				.1%	1%		.1%
3621 Ready anchor					1		1
					1%		.1%
3622 By bow				7			7
				.9%			.4%
3623 Scope	1			1			2
	1.8%			.1%			.1%
3640 Unplanned events	3	2	13	25	3	2	48
	5.5%	2.9%	4.4%	3.3%	3%	.4%	2.8%
3650 Waterskiing				2			2
				.3%			.1%
3651 Locations				4			4
				.5%			.2%
3653 Obstructions	1			11		2	14
	1.8%			1.4%		.4%	.8%
3654 Time of day				1			1
				.1%			.1%
3656 Observation	1			2		1	4
	1.8%			.3%		.2%	.2%
3657 Conditions				5			5
				.7%			.3%
3658 Operation				2			2
				.3%			.1%
3659 Recovery				6	1		7
				.8%	1%		.4%
3660 Wave jumping						22	22
						4.8%	1.3%
3672 Shortening sail		2	1				3
		2.9%	.3%				.2%
3673 Spilling wind		3					3
		4.4%					.2%
3674 Gybe control		1					1
		1.5%					.1%
3690			1				1
			.3%				.1%
3710 Running lights				1			1
				.1%			.1%

	Missing Other	Sail	Open Small	Open Power	Cabin Power	PWC	Total
3711 Configuration						1	1
						.2%	.1%
3712 Operation					1		1
					1%		.1%
3720 Interpreting others				2			2
				.3%			.1%
3750 Unlighted objects				10	6		16
				1.3%	6%		.9%
3770 Adjust speed	1			24	9	1	35
	1.8%			3.2%	8%	.2%	2.0%
3780 Illuminating self				2	1		3
				.3%	1%		.2%
3810 To Crew		1		7	1		9
		1.5%		.9%	1%		.5%
3821 Audible signals				1			1
				.1%			.1%
3823 Hails&hand signals				1		3	4
				.1%		.7%	.2%
3830 Other	1			4			5
	1.8%			.5%			.3%
4100 Falls Overboard		2		4		1	7
		2.9%		.5%		.2%	.4%
4110 Handhold&footing		1	1	6	3	1	12
		1.5%	.3%	.8%	3%	.2%	.7%
4120 Inside cockpit&cabin		1		6	2		9
		1.5%		.8%	2%		.5%
4130 Remain seated			13	16			29
			4.4%	2.1%			1.7%
4200 Wear PFD Under Risk		2	1	5	1		9
		2.9%	.3%	.7%	1%		.5%
4210 High risk of immersion		2	26	19	1	4	52
		2.9%	8.9%	2.5%	1%	.9%	3.0%
4220 Difficulty finding in water		1	2	4			7
		1.5%	.7%	.5%			.4%
4230 Difficulty recovery			2	1			3
			.7%	.1%			.2%
4240 Unable to swim			14	12	1		27
			4.8%	1.6%	1%		1.6%
4250 Cold water	1	1	12	20		1	35
	1.8%	1.5%	4.1%	2.6%		.2%	2.0%
4260 Unconscious				1			1
				.1%			.1%

	Missing Other	Sail	Open Small	Open Power	Cabin Power	PWC	Total
4310 Sun&heat&hypothermia				3			3
				.4%			.2%
4320 CPR			1	2		1	4
			.3%	.3%		.2%	.2%
4400 Voluntarily Entering Water				8			8
				1.1%			.5%
4430 Trail line			1				1
			.3%				.1%
4440 Facilitate egress			2	1			3
			.7%	.1%			.2%
4450 Flotation	2		4	7	1		14
	3.6%		1.4%	.9%	1%		.8%
4460 Swimming after boat	1		1	1			3
	1.8%		.3%	.1%			.2%
4470 Stay clear of boat				1	1	1	3
				.1%	1%	.2%	.2%
4510 Control own	2	5	25	74	9	20	135
	3.6%	7.4%	8.5%	9.7%	8%	4.4%	7.8%
4520 Control others				1			1
				.1%			.1%
4530 Recognizing signs				1			1
				.1%			.1%
4540 Protecting impaired				1			1
				.1%			.1%
5100 Rough Conditions		1	2	9	1		13
		1.5%	.7%	1.2%	1%		.7%
5110 Recognizing onset		1		3			4
		1.5%		.4%			.2%
5130 Responding		2	1	6	1	4	14
		2.9%	.3%	.8%	1%	.9%	.8%
5131 Wearing PFDs			1	9			10
			.3%	1.2%			.6%
5132 Seeking shelter				1			1
				.1%			.1%
5134 Adjusting speed				8	2	3	13
				1.1%	2%	.7%	.7%
5135 Adjusting direction			1	1	1		3
			.3%	.1%	1%		.2%
5136 Balancing boat			1				1
			.3%				.1%
5137 Bailing --pumping			1	4	1		6
			.3%	.5%	1%		.3%

	Missing Other	Sail	Open Small	Open Power	Cabin Power	PWC	Total
6100 Falls Overboard				1	1		2
				.1%	1%		.1%
6120 Throw device immediately		1					1
		1.5%					.1%
6140 Stop&turn immediately		1		1			2
		1.5%		.1%			.1%
6150 Approach --power		1					1
		1.5%					.1%
6210 Boat for flotation		1	6	11			18
		1.5%	2.0%	1.4%			1.0%
6220 Other objects					1		1
					1%		.1%
6240 Gaining conspicuity					1		1
					1%		.1%
6250 Conserving energy		1					1
		1.5%					.1%
6280 Entanglement			1				1
			.3%				.1%
6312 Electrical source		1					1
		1.5%					.1%
6400 Seeking Help		3	3	2		2	10
		4.4%	1.0%	.3%		.4%	.6%
6410 Radio at first sign		1			1		2
		1.5%			1%		.1%
6420 Distress signals				1			1
				.1%			.1%
9100 Insufficient Information	2	4	9	44	6	13	78
	3.6%	5.9%	3.1%	5.8%	6%	2.9%	4.5%
9200 Act of Nature		1	1	1	1		4
		1.5%	.3%	.1%	1%		.2%
	55	68	293	759	108	456	1739
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Appendix E

ON IDENTIFICATION OF PROMISING INTERVENTIONS FOR BOATING RISK MANAGEMENT

This appendix incorporates the contents of Section IV.D.

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1 Context

This part of the report, Part II, follows up on Part I, "A Framework for Undertaking Policy Analysis for Boating Safety." Part I presented an overview of policy analysis in the context of boating safety. In it, a number of steps were identified for undertaking policy analysis in general and policy analysis for boating risk management in particular. Figure 1 shows the list. Here

- Specify the problem
- Identify Alterative Options
- Specify Key Interested Parties
- Indicate Ways Individuals Collect Information
- Specify Decision Processes of Stakeholders
- Specify Relevant Attributes
- Valuation of Attributes
- Evaluation of Alternatives
- Trial Use & Feedback to Problem Definition

Figure 1: Framework of steps in policy analysis (from Part I)

in Part II we discuss in further detail the problem of identifying alternative options.

Quite a number of techniques are available, and can be recommended, for generating alternatives.[1] These techniques, discussed in Part I, include brainstorming, group decision support systems, nominal groups, and the Delphi method. Our focus here, in this Part, is on techniques for problem structuring. Independently of which methods are used for generating alternatives,

[1] Regarding "can be recommended," we note that although the various techniques have good face validity and enjoy widespread acceptance and use, empirical studies of their effectiveness have not been unequivocally enthusiastic.

it is essential to have a way to represent—in a simple, clear, and neutral fashion—the problem(s) for which the generated alternatives are candidate solutions. Such representations will be useful in generating alternative solutions (whatever method is used), for communicating with relevant stakeholders, and for specifying what the alternative solutions should be solutions of.[2] Thus, we might also think of the problem structuring effort as an exercise in specifying the problem in depth. This has the merit of forcing the stakeholders to specify the problem and its components in a way that is clear and open to review. However we fit it into our framework, doing this is an essential part of policy analysis.

Our primary, most fundamental technique recommended for problem structuring in the context of policy analysis for boating safety is called the *method of use cases,* which we shall now present and discuss.

2 Structuring the Problem with Use Cases

Use cases are now a well-accepted component of system design methodology. Invented only recently (Ivar Jacobson usually gets the credit [9]), use cases are simply short descriptions of more or less complete interactions of one or more actors (typically, people) with a system. They are often used to specify representative and important cases for *computer* system design (the system should be able to handle the use cases) and evaluation (the system should handle the cases properly). They are, however, intended and used for system design generally, whether or not computers are relevant. Use cases are also valued as communication devices. Written in plain language, they are creatable and understandable by just about all stakeholders. Thus, although we shall have to modify somewhat the methodology, for present purposes use cases have much to recommend them. They have of great merit of being not far from "what we already do" in many design situations. See [4, 12] for introduction to and further references for use cases. (These references are about a complete design methodology for systems, called UML (unified modeling language). In §2.2 we shall make use of activity diagrams, another element of UML.)

[2] In the jargon of systems analysis and design, we would say that these representations are useful for validation ("Did we build the right system?") and for verification ("Did we build the system right?").

In the remainder of this section we illustrate the method of use cases, as applicable to the problem of policy analysis for boating safety.

2.1 Use Cases

2.1.1 Use case 1

2.1.1.1 Use case The course of events begins with two motor vessels heading for a meeting under a bridge from opposite directions. It is shortly after dusk. Neither vessel is displaying running lights. Noise from the highway obscures the sounds of the vessels from each other. The two vessels come into view too late to avoid collision under the bridge. A passenger in one of the vessels is thrown into the water and knocked unconscious. Not wearing a PFD (personal floatation device) the passenger drowns during the ensuing confusion.

2.1.1.2 Comments This use case is an example of a sequence of events that might be diagrammed as follows:

- collision with another vessel → falls overboard → fatality

or, if we are more specific and detailed, the sequence might be:

- consumption of alcoholic beverages →
  distraction →
  ⋮
  collision with another vessel →
  falls overboard →
  fatality

and so on.

Note that certain details are (very likely) relevant and worth recording. These details will distinguish different versions of the basic scenario and are intended to be materially useful in finding, designing, and evaluating possible interventions. For example, the collision occurred in a constrained area, not on the open waters. Certain entirely preventable conditions obtained: no life vest on the victim, no display of running lights (and perhaps excessive speed

and lack of attention?) Note as well the fundamental conceptual elements in the story:

1. Vessels
2. People (here all passengers)
3. The environment (the bridge, the confined waterway)
4. The legal context (rules of the road, lights and passage, etc.)
5. States or conditions (dusk, lack of headlamps, etc.)
6. Events (collision, followed by fall in the water and disabling of passenger)

These concepts help to abstract the situation and allow us to see patterns across many circumstances. A main purpose of use cases is to span or cover the principal situations in order for this abstraction to be most useful.

2.1.2 Use case 2

2.1.2.1 Use case The course of events begins when the passengers on the boat become aware of the onset of a storm and begin to race back to home port. High winds create high waves and make the boat roll unpredictably. Operating at excessive speed (for the conditions) in a storm, the boat avoids capsizing, but one of the passengers is thrown overboard. In seeking to recover the passenger under the conditions, the boat's pilot/driver inadvertently strikes the victim, causing serious injury.

2.1.2.2 Comments This use case is an example of a sequence of events that might be diagrammed as follows:

- falls overboard → struck by boat or propeller → serious injury

Note, again, the fundamental conceptual elements in the story:

1. Vessels (here just one)
2. People (here all passengers)

3. The environment (the weather, high seas)

4. States or conditions (excess speed in unstable conditions)

5. Events (passenger falls into the water; passenger hit by boat)

Again, these concepts help to abstract the situation and allow us to see patterns across many circumstances. A main purpose of use cases is to span or cover the principal situations in order for this abstraction to be most useful.

2.2 Diagrams

Plain and simple English should be the main vehicle for recording use cases, for it is the mode of expression most accessible to the broad range of stakeholders in the policy analysis process. Even so, it is sometimes helpful to augment the textually-expressed used cases with diagrams. Doing so is standard practice in systems analysis, and what the UML people (see References section) call activity diagrams are the main representation tool (at least initially). Activity diagrams are somewhat like flowcharts in that they describe a sequence of events of various sorts. They differ from flowcharts in allowing parallelization: more than one thing can happen at once (accelerate the boat and hit a wave), and ordering of events can (if appropriate) be ignored for purposes of abstraction.

Activity diagrams have a large literature and established usage and pedigree. More importantly, they—together with use cases, which should come first—are an apt tool given the needs of policy analysis for boating safety.[3]

Standard discussions of activity diagrams can be found in the UML literature, e.g. [4, 12]. In this section, we illustrate the application of (a modified form of) activity diagrams to use case 1. The diagram is presented in Figure 2.

We interpret the diagram as follows. The solid circle at the top indicates the start of events. Time flows in the direction of the diagram's arrows. Horizontal lines indicate synchronization and subsequent parallel processes or events. The first of these in Figure 2 indicates that one state (of the

[3]These diagrams, in UML, are variants of several other methods, including event diagrams, state modeling techniques, and Petri nets.

environment) and two events (boats 1 and 2 heading towards the bridge) obtain and occur at roughly the same time. Subsequently, the boats collide and the environment remains as it was. Then the passenger falls overboard, is injured and drowns, while the environment remains the same. The solid cirle inside the open circle indicates that the course of events is complete.

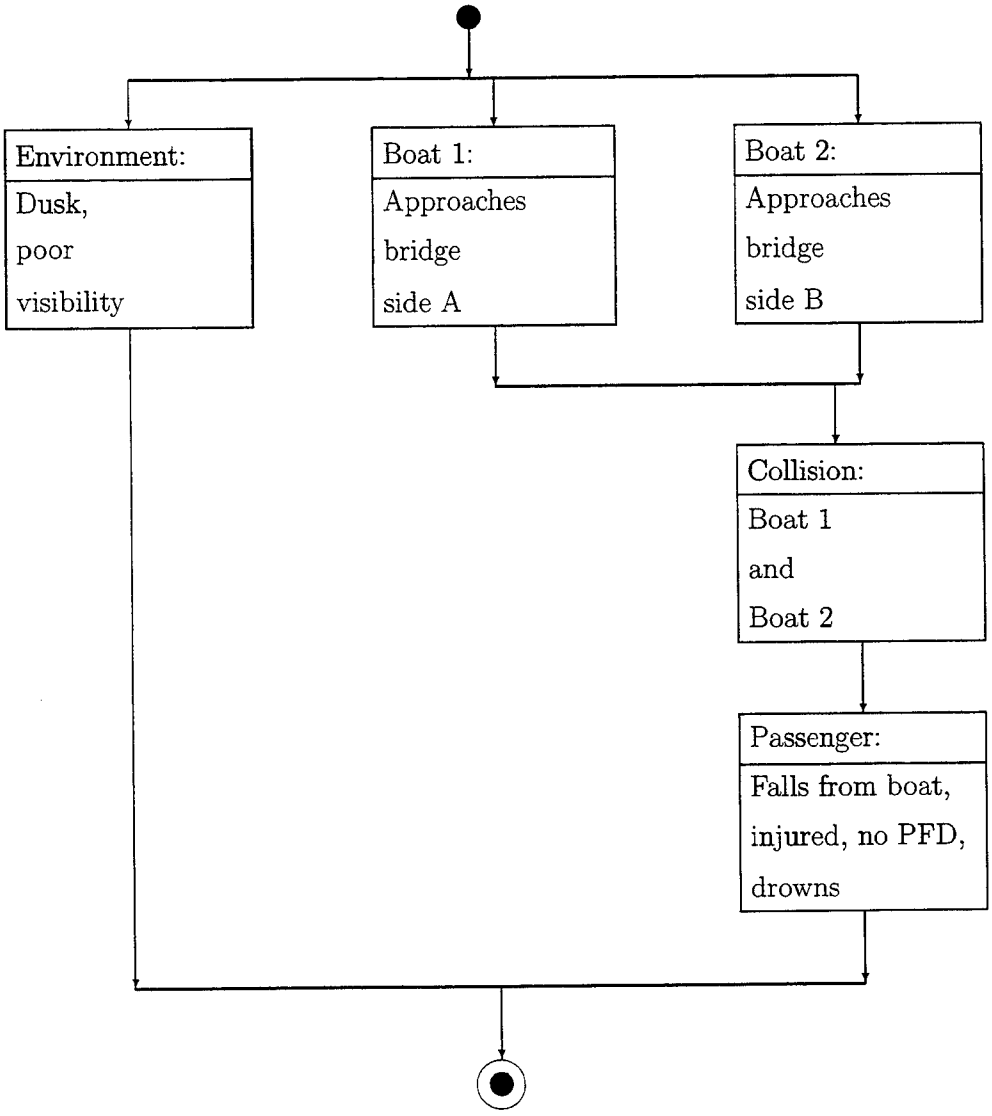

Figure 2: Activity diagram for use case 1

2.3 Discussion

Among other things, the use cases serve the purpose of focusing the exercise of identifying contributing causes and, therefore, alternative options. Consider the examples to hand, use cases 1 and 2, §§2.1.1-2.1.2. We may list possible alternative solutions, for example:

- Use case 1

    1. Provide enhanced aids to navigation for bridges and other constricted areas that create collision hazards because of restricted visibility.
    2. Increase the requirements to wear PFDs, and change liability laws to put increased onus on boat operators to prevent passengers from not wearing PFDs.
    3. Require all boats to have lighting that automatically turns on when the ambient light is sufficiently low.
    4. Require and install controlling electronics that automatically reduces boat speed in hazardous areas.
    5. Establish rules and educate people so that hazards are encountered less often.
    6. Design and make available an apparatus that reduces the chance of falling overboard, and/or sustaining impact injuries, in a collision.

- Use case 2

    1. Institute better training and education programs, and change the liability laws to encourage boaters to participate in these programs and to attend to current weather conditions (e.g., with radios).
    2. Design and make available an apparatus that reduces the chance of falling overboard, and/or sustaining impact injuries, in a collision.
    3. Require propeller guards on boats.
    4. Increase the requirements to wear PFDs, and change liability laws to put increased onus on boat operators to prevent passengers from not wearing PFDs.

Remember: These are just examples. Part of the purpose of the use cases is to foster understanding of the problem and to stimulate the alternative generation process, however it is conducted (brainstorming, group DSS, and so on).

Use cases (and their attendant diagrams) constitute problem structuring for the inherently creative, weakly structured process of identifying alternative options for problem solution. Once such options are to hand—for example as above—the analysis can continue as indicated in Part I. For example, in specifying key interested parties it will be necessary to look both at the proposed alternative solution *and* at the problem itself as represented in the use case. Ultimately, the value of an alternative depends at least in part on what other alternatives are available. Who the interested parties are for a given alternative must also depend in part on the problems—the use cases—for which the alternative is being considered as an option. Besides the interested parties explicitly mentioned in an alternative, there may be parties implicitly affected, given the context, i.e., the problem for which the alternative is a possible solution.

The point generalizes to the rest of the steps in the policy analysis framework (see Figure 1, page 1). The ways individuals collect information and the decision processes of stakeholders depend critically upon who the actual stakeholders are. Similarly specifying relevant attributes, valuing these attributes, and indeed evaluating the alternatives all depend critically upon who is counted as "in," as a legitimate stakeholder or interested party, and who is not.

Because problem structuring—both in general and when the use case methodology is employed—is so critical to the policy analysis process, it is worth inquiring further into its antecedents. Producing use case is inherently a creative and weakly structured enterprise (like the subsequent process of identifying alternatives). What can be done to facilitate this process? Very little is known about this, but careful examination of relevant data is surely to be recommended. What follows in this Part addresses the data exploration issue in the context of policy analysis for boating safety. In particular, we address the issue of proper structuring of data for this purpose. The point we want to make is that creation of a full and accurate set of use cases will be materially aided by careful examination of available data, and that the success of such an examination will require proper structuring of the data. Thus, in §3 we discuss how the data ought to be organized and structured,

and in §4 we discuss how the data may be exploited.

3 View the data

Intervention identification—or alternative identification—inevitably begins with exploration of whatever data are available. In the present case of boating risk management, there is happily a rich source of data in the form of Coast Guard accident reports (see for example [14]). Other sources are available as well. Data are available both in record (or atomic) form (e.g., individual accident reports) and in aggregated summaries (e.g., [14]). As useful and as suggestive as the existing data are, it is worth attending to the problem of structuring the data for present purposes. To this end, there are two main questions that need to be addressed:

1. In what format(s) should the data be presented?
2. How (for purposes of risk analysis) should the data be organized?

We now address these questions individually.

3.1 Data format

It is of course necessary to have valid and reliable data upon which to base any policy recommendations that would come out of an exercise in risk analysis. That issue is beyond the scope of this part of the report. What concerns us here is—once valid data are to hand—proper representation of data for purposes of (risk) analysis. By "data" we mean here the more narrow sense of the term, to include only the structured form of data, commonly stored in database management systems. We explicitly mean to exclude textual and other unstructured forms in this discussion (but not from the analysis process itself).

For concreteness, consider the sort of data collected in Coast Guard boating accident reports (see [14, pages 3f]). We can think of these data, once transcribed, as residing in tables. Rows of the tables correspond to particular accidents and columns corrspond to values of data items collected regarding the accidents. Figure 1 illustrates a *portion* of a *hypothetical* such table. We say that these data are in *record* or *relational* format.[4]

[4]We are deliberately glossing over technical details that need not detain us here.

AccidentID	...	Wind	Visibility	Day	...
⋮	⋮	⋮	⋮	⋮	⋮
1251	...	storm	poor	yes	...
1252	...	storm	poor	yes	...
1253	...	storm	poor	yes	...
1254	...	storm	poor	no	...
1255	...	storm	poor	yes	...
1256	...	storm	poor	no	...
1257	...	storm	poor	no	...
1258	...	storm	poor	no	...
1259	...	storm	poor	yes	...
1260	...	storm	poor	yes	...
1261	...	storm	poor	no	...
1262	...	storm	fair	yes	...
1263	...	storm	fair	no	...
1264	...	storm	fair	yes	...
1265	...	storm	fair	no	...
1266	...	storm	good	no	...
1267	...	strong	poor	yes	...
1268	...	strong	fair	yes	...
1269	...	strong	fair	no	...
1270	...	strong	good	no	...
1271	...	strong	good	no	...
1272	...	moderate	fair	yes	...
1273	...	moderate	fair	yes	...
1274	...	moderate	fair	no	...
1275	...	moderate	good	no	...
1276	...	moderate	good	yes	...
1277	...	moderate	good	no	...
1278	...	moderate	good	yes	...
1279	...	light	fair	yes	...
1280	...	light	good	no	...
1281	...	none	good	yes	...
⋮	⋮	⋮	⋮	⋮	⋮

Table 1: Accident report data in record format. (All data are hypothetical.)

Getting the relevant data into a properly designed relational, or record, format is important, even essential, for having a sound basis for analysis. In the next section, §3.2, we discuss how this can be done in the present context and for present purposes. Our point in this section is that while relationally-formatted data are necessary and foundational, this is *not* the proper format for analysis in general and risk analysis in particular. Instead, data should be made available in crosstabulations, or *crosstab* format. A main reason for valuing the record format is that it can be systematically transformed into crosstab format (more on this below).

The crosstab format is perhaps best understood with examples. Table 2 presents crosstab representation of the `Wind` and `Visibility` data from Table 1.

Wind	*Visibility*			
	Poor	*Fair*	*Good*	
Storm (Over 25 mph)	12	3	1	16
Strong (15–25 mph)	1	2	2	5
Moderate (7–14 mph)	0	3	4	7
Light (0–6 mph)	0	1	1	2
None	0	0	1	1
	13	9	9	31

Table 2: Data from Table 1 in crosstab format, crossclassifying wind and visibility conditions for boating accidents. See "Boating Accident Report" form, [14, page 3]. (All data are hypothetical.)

Comments:

1. The entries in the crosstab table represent counts of observations. For example, there were 12 cases of accidents in which storm conditions applied and visibility was poor.

2. The numerical entries outside the table represent summary (or "marginal") totals. For example, there were 31 observations in all, 16 under storm conditions, 13 under poor visibility.

3. Figure 2 is a *two-dimensional* crosstab. Crosstabs of arbitrarily higher dimensionality (3, 4 ... dimensions) are legitimate and use the same principles of analysis and statistics.

4. An n-dimensional crosstab ignores ("sums out") all data from dimensions not in it. For example, in Figure 2 all information about time of day is lost.

5. The point of a crosstab reprsentation is to look for and test for relatively simple and significant associations among variables of interest. Excellent statistical and graphical techniques exist for exploration and analysis of data in crosstab format. See [1] for recent relevant work. See [6, 5] for a powerful, general statistical approach to these kinds of data.

6. An essential part of any such analysis is to search for "hidden variables" that greatly alter the association (making it significant or insignificant) of other variables. For example, the association between wind and visibility in producing accidents may change greatly depending upon time of day—or it may not. To the extent that these kinds of questions cannot be answered and answered easily, confidence in the analysis can only be weakened. (And they often cannot be answered with existing reports, let alone answered easily.) Here we see one of the main benefits of proper data representation. Such representation, supported by computerization for rapid calculation, can do much to support effective understanding of a mass of data, even by technically unsophisticated users.

7. The crosstab format is an especially convenient form of representation for data. It does not add any information beyond that present in the underlying relational representation. Notice as well that the crosstab format is especially compact and understandable. Compare the size of the tables in Tables 1 and 2. Table 2 summarizes 31 records from Table 1. Had there been 31,000,000 records instead, the size of Table 2 would not have changed, only the sizes of the numbers it records.

In emphasizing the importance of getting relevant data in crosstab format we are in accord with present-day practice. The data warehousing industry is in large part motivated by the need to get data in good relational format so that they can then be transformed into crosstab format for subsequent use. This, although often by different names, is standard practice in OLAP (on-line analytical processing) applications (cf., [8, p. 179] on "the 'cube'

foundation for multidimension DBMS [database management systems] datamarts"; [3, p. 45] on "hypercube data representations"; [13] and [2] on "cubes"). Our reasons for using the crosstab form for data representation are simple and essentially identical to why it is now used so widely in OLAP applications (and has long been essential in statistics): the crosstab form easily accommodates qualitative variables and (most importantly) it has been demonstrated to be a natural representation for the sorts of reports and hypotheses users—managers and scientists—typically are interested in.[5] (See also the literature on information visualization. For a reviews see [10, 11].)

The crosstabbed data are not only valuable for indicating significant associations between variables. They are also valuable for generating use cases and policy options. They help us understand which use cases to create (or discover). Consider, for example, Table 2, page 12 and compare it with use case 2, §2.1.2, page 4. The Table tells us (hypothetically) that half of the accidents occur under storm conditions (16/31), while few accidents of this type occur under calm conditions, even when visibility is poor. So, these data tell us that we need a story—a use case—to explain what happens to cause accidents, and other unwanted results, under stormy conditions. Surprisingly (remember: these are hypothetical data), these data also tell us we likely do not need use cases to explain the association of visibility with these types of hypothetical accidents, since there isn't much of one.

Finally, we note that given the comparatively small scale of the Coast Guard's data (fewer than 10,000 accident reports per year) it is not difficult to generate crosstabulations of data in relational format. While crosstab commands do not belong to standard SQL, they are often implemented in particular products.[6] For example, in Microsoft's Excel spreadsheet product crosstab tables are called pivot tables and there is built-in functionality for creating them. Excel is good in this regard for datasets of thousands of records. Also, Microsoft's Access database management product (like Excel, part of the Office suite, hence inexpensive and widely available) has built-in

[5]We do not want to suggest that the data format evident in Table 2 is the only kind of crosstab representation for qualitative data. It isn't and the methods we discuss here are not limited to this particular format, but scope limitations prevent us from elaborating upon the point. See the discussion in [5] of the condensed ordinal form for one example of an alternative crosstab representation.

[6]SQL = structured query language. This is the standard interface for interacting with database management systems.

support for creating and saving crosstab tables. Its capacity also satisfies requirements of the Coast Guard for data from boating accident reports.[7]

In sum, proper structing of the analysis and the problem itself is assisted by proper structuring of the underlying relevant data, and that entails getting the data into crosstab format. We now turn to the question of how *semantically* to think about the data for the purposes of risk analysis and how then to put these data into relational (record) format for transformation into crosstab format.

3.2 Data organization

Existing practice in risk management is relevant and helpful to the problem of thinking about how boating risk data should be oranized (conceptually and for present purposes, if not in the original records collected). There is no established doctrine or methodology for organizing the factors having to do with risk management, but there are examples of good practice and these may be drawn upon for present purposes.

The OECD (Organisation for Economic Co-operation & Development) Risk Assessment Dictionary/Thesaurus [7] is a particularly apt example. Developed for the purpose of comparing different national laws pertaining to chemical and environmental accidents, the Thesaurus embodies a general theory for, or conceptual framework of, the important relevant factors in this area of risk assessment. Moreover, the framework is intended to be generic; the fact of its international acceptance attests to some success in this regard. See Appendix A for summary information on the OECD Risk Assessment Dictionary/Thesaurus.

The OECD Thesaurus design should be seen as useful and suggestive, rather than as a finished solution to the data organization structuring problem for boating risk management. With this in mind, it is possible to begin to sketch an analogous structure for the boating risk management problem. In doing so, we will use a "flat" structure, instead of the hierarchical one used by the OECD Thesaurus. Instead of "generic elements," "sub-elements," and so on, we will use the term "dimensions."

[7]We make these comments not by way of endorsing Microsoft products; far from it. In fact, we would recommend avoiding such products where practicable. Rather, our point is that commonly-available commercial products—rather than exotic specialized products—can be used for the tasks suggested.

Clearly, the most important dimension may be called *undesired outcomes* (see 1c in Figure 4, page 26). Judging by the Coast Guard's boating statistics reports (e.g., [14]), data are now being collected on the following categories of undesired outcomes:

1. Fatalities, due to drowning
2. Fatalities, other than due to drowning
3. Injuries
4. Vessel damage greater than $500, or loss of vessel
5. Property damage, other than vessel damage or loss

We may take these as the fundamentally bad outcomes, the risks of which are to be analyzed and reduced in some way. Notice that use case 1, §2.1.1, is about a fatality due to drowning and (presumably) vessel damage greater than $500, or loss of vessel. Use case 2, §2.1.2, is about an injury. Ideally, use cases should be developed to represent each of the categories of undesired outcomes, and to represent all of the main kinds of circumstances ("causes") that create these undesired outcomes.

The National Boating Accident Report form in effect supplies a number of dimensions presumably relevant to predicting or explaining the undesired outcomes. Many of these dimensions have analogs in the OECD Thesaurus. For example, the dimension *type of accident* has in the Boating Accident Report the following possible values:

1. Grounding
2. Capsizing
3. Flooding
4. Sinking
5. Fire or Explosion (Fuel)
6. Fire or Explosion (Other than fuel)
7. Fallen Skier

8. Collision with Vessel
9. Collision with Fixed Object
10. Collision with Floating Object
11. Falls Overboard
12. Falls in Boat
13. Hit By Boat or Propeller
14. Other (Specify)

(A close analog of this dimension in the OECD Thesaurus would be 1a, Figure 4, page 26.) Notice that use case 1, §2.1.1, is about a collision with vessel and a falling overboard. Use case 2, §2.1.2, is about a falling overboard and a being hit by boat or propeller. As in the case of undesired outcomes, use cases should be developed to represent each of these categories, and to represent all of the main kinds of circumstances that involve them.

There is more to be said on this subject (see Appendix B for additional details), but the main point may be simply stated.

For purposes of analysis, it would be especially convenient if the boating accident data could all be represented in record form (relationally) in a single table. This makes the data more accessible to those having spreadsheet skills but lacking database skills. It is also especially convenient for transforming the data into crosstab form, either using a spreadsheet (such as Excel) or a database (such as Microsoft Access). In fact, without undue violence to proper database design, the Coast Guard's boating safety data may be so represented.

4 Identify high impact categories for promising interventions

Careful analysis of available data after it has been put into crosstab format will very likely yield insights regarding where interventions, if effective, would produce most value and what causal regimes are at work in boating

accidents. There is much that is useful and suggestive in these regards already in the Coast Guard's current publications. For example, in 1994 it is reported that 79% of all accidents involve "operator controllable factors" as opposed to "vessel/environmental factors" [14, page 15]. Of the operator controllable factors the great majority of accidents are attributed to carelessness (1792 cases; use cases 1 and 2), improper lookout (968; use case 1), and speeding (733; use case 2), while only 11 were reported due to improper weight distribution. This suggests (and only suggests absent careful analysis of the data and evaluation of intervention costs) that interventions designed to redress improper weight distributions should have relatively low priority, while interventions aimed at reducing the problems of carelessness, improper lookout and speeding (see use cases 1 and 2, §§2.1.1–2.1.2) should have high priority.

Analysis of the data, even of the data already available, is likely to provide plausible categories of factors to be addressed with high priority by interventions. Let us assume that among these are in fact carelessness, improper lookout, and speeding. What the existing data are likely to be less valuable for is uncovering the causal regimes that produced the accidents. (This will be true even when the data are put into crosstab form and properly analyzed, although doing so will help greatly.)

Understanding the causal processes at work, rather than merely being aware of associations among high-level variables, will be essential for designing effective interventions. For example, "carelessness" and "improper lookout" are by far the most frequently cited categories of factors involved in boating accidents. Carelessness about what? Improper lookout for what? Without some additional knowledge, or at least working hypotheses, regarding what actually happens in these accidents, it is difficult to justify investment in, or even investigation of, remedial interventions. Perhaps the intervention under consideration really only addresses a circumstance that occurs less often and less disasterously than improper weight distribution.

Recall now our previous discussion of events associated with accidents (§B, page 28). For fatalities, the Coast Guard reports up to three contributing events. The summary data, as reported in [14, page 17] for example, do not give causal profiles of accidents, but it would appear that there may be some information in this regard in the underlying raw data. Even so, what is reported is suggestive. For example, apparently (given the data in the report) the following event sequences lead to fatalities more than rarely:

- collision with another vessel → falls overboard → fatality
  (Use case 1, §2.1.1.)
- falls overboard → struck by boat or propeller → fatality
  (Use case 2, §2.1.2, but injury instead of fatality.)
- capsizing → falls overboard → fatality

On the other hand, it would appear (given the data in the report) that the following sequences rarely or never happen:

- falls overboard → collision with another vessel → fatality
- capsizing → fire/explosion → fatality

This sort of information about event sequences that do (and do not) often lead to undesired outcomes points towards the kind of information needed to discover, design, and evaluate possible interventions for managing boating risk.

What is needed is a methodology, or general approach, that leads to plausible working hypotheses about the causal nexuses involved in accidents. Such an approach should use available hard data (we have above remarked on how to do this). It should as well use expert knowledge subjectively obtained, yet be public and communicatable for broad discussion. In short, we need a way of adding to the hard data available additional information leading to a structuring of the problem to reflect the causal paths involved in boating accidents. The method of use cases, or the proper employment of them, is just such a technique.

5 Summary and Discussion

A framework of stages in policy analysis was presented and discussed in Part I of this report. That framework is repeated in Figure 1, page 1. Part II of the report has focused on the method of use cases for detailed problem specification (step 1 in the framework) and identification of alternative solution options (set 2 in the framework). Part II has also provided indications of how use cases can figure into, and contribute to, subsequent stages in the policy analysis framework.

Use cases, as the concept has been developed here, are brief stories about something that has gone wrong. They are meant to capture representative situations causing accidents. Their source is expert judgment, informed by analysis of data. As such, they are a way of extending existing hard data by importing subjectively assessed expertise. By recording these extensions in brief and clear passages of English, and in diagrams, use cases can be displayed to all stakeholders for purposes of validation (including correctness and completeness).

Moving forward in the stages of policy analysis, the use cases are critical for identification of alternative options, since they tell us much about the main causal factors at work contributing to the undesired outcomes. In short, the use cases help us focus on what is most important and help us ignore what is less important. They also are helpful for identifying stakeholders and relevant attributes for evaluation of alternatives.

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A Summary of OECD Risk Assessment Dictionary/Thesaurus Design

The philosophy underlying the OECD (Organisation of Economic Co-operation and Development)[8] Thesaurus is easily sketched:

[8]http://www.oecd.org, accessed June 24, 1999:

> The Organisation for Economic Co-operation and Development has been called a think tank, monitoring agency, rich man's club, an unacademic university. It has elements of all, but none of these characterisations captures the essence of the OECD.
>
> The OECD groups 29 member countries in an organisation that, most importantly, provides governments a setting in which to discuss, develop and perfect economic and social policy. They compare experiences, seek answers to common problems and work to co-ordinate domestic and international policies that increasingly in today's globalised world must form a web of even practice across nations. Their exchanges may lead to agreements to act in a formal way - for example, by establishing legally-binding codes for free flow of capital and services, agreements to crack down on bribery or to end subsidies for shipbuilding. But more often, their discussion makes for better informed work within their own governments on the spectrum of public policy and clarifies the impact of national policies on the international community. And it offers a chance to reflect and exchange perspectives with other countries similar to their own.
>
> The OECD is a club of like-minded countries. It is rich, in that OECD countries produce two thirds of the world's goods and services, but it is not an exclusive club. Essentially, membership is limited only by a country's commitment to a market economy and a pluralistic democracy. The core of original members has expanded from Europe and North America to include Japan, Australia, New Zealand, Finland, Mexico, the Czech Republic, Hungary, Poland and Korea. And there are many more contacts with the rest of the world through programmes with countries in the former Soviet bloc, Asia, Latin America - contacts which, in some cases, may lead to membership.
>
> Exchanges between OECD governments flow from information and analysis provided by a Secretariat in Paris. Parts of the OECD Secretariat collect data, monitor trends, analyse and forecast economic developments, while others research social changes or evolving patterns in trade, environment, agriculture, technology, taxation and more. This work, in areas that mirror the policy-making structures in ministries of governments, is done in close consultation with policy-makers who will use the analysis, and it underpins discussion by member countries when they meet in specialised committees of the OECD. Much of the research and analysis is published.

> In brief, the risk assessemtn process is divided into four **Generic Elements**. Each *Element* is further divided into **sub-elements** or terms that analyze the various concepts contained within each *Element*. The *sub-elements* and **terms** are finally defined by **categories** of **descriptors** that characterize the terms with operational singularity. [7, page 11]

Figure 3, page 25, presents the four generic elements for the OECD Thesaurus. Figures 4 and 5, pages 26–27, show the sub-elements for the Thesaurus.

1. Generic Element I

   Identification of the sources with the potential to cause undesired outcomes to the subjects of concern.

2. Generic Element II

   Identification of possible sequences of events leading to the loss of containment of the potential to cause undesired outcomes to a subject of concern. Estimation of possible distributions of both the released potential and the subjects of concern over time periods within a domain delimited by specified boundaries or end-points.

3. Generic Element III

   Identification and description of how the specified undesired outcome is related to the intensity, time and mode of contact of a specified potential to cause the undesired outcome to the subject of concern.

4. Generic Element I

   Identification of the basis for estimating and expressing the likelihood that a specified undesired outcome of a specified magnitude for a specified subject of concern will occur and description of the quality/uncertainty of such estimates; comparison of the estimates with relevant standards and guidelines; and evaluation of the impact of specified alternative assumptions on the estimates.

Figure 3: OECD Risk Assessment Thesaurus: Generic Elements

1. Generic Element I

    (a) Sources with potential to cause undesired outcomes

    (b) Subjects of concern

    (c) Undersired outcomes

2. Generic Element II

    (a) Basis for generating possible sequences of events

    (b) Basis for estimating distribution of the released potential

    (c) Basis for estimating distribution of subjects of concern

    (d) Basis for boundaries and endpoints of distribution estimates

3. Generic Element III

    (a) Mode of contact between the potential to cause the undersired outcome and the subjects of concern

    (b) Basis for the relationship used to predict how the specified undesired outcome is related to contacts with the potential to cause the undesired outcome

    (c) Dimensions/measurement units of the potential used in predicting undesired outcomes

    (d) Dimensions/measurement units used to express the predicted undesired outcome

Figure 4: OECD Risk Assessment Thesaurus: Sub-Elements for Generic Elements I–III

4. Generic Element I

   (a) Basis for estimating that the likelihood that specified undesired effects will occur

   (b) Method of expressing the likelihood that na undesired effects) will occur

   (c) Description of the quality/uncertainty of estimates of likelihood

   (d) Undesired outcome of a specified magnitude for a specified subject of concern

   (e) Nature of standard or guideline to which estimates are compared

   (f) Type and form of information needed for comparisons of estimated likelihood

   (g) Identification of specified alternative assumptions whose impacts on likelihood are to be evaluated

   (h) Evaluation of the impact of alternative assumptions on estimates of likelihood

Figure 5: OECD Risk Assessment Thesaurus: Sub-Elements for Generic Element IV

B Further Remarks on Representing Coast Guard Accident Data in Simple Relational Format

For purposes of analysis, it is especially convenient if the boating accident data could all be represented relationally in a single table. This makes the data more accessible to those with spreadsheet skills but lacking database skills. It is also especially convenient for transforming the data into crosstab form. The purpose of this section is to continue the discussion from the main body of the report, demonstrating that without undue violence to proper database design, the Coast Guard's boating safety data may be so represented.

* * *

Interestingly, and significantly for our present task of structuring the analysis of risk, the Coast Guard reports—for fatalities—whether the type of accident (grounding, capsizing, ...) was event number 1, 2, or 3 in the "accident sequence" [14, page 17]. Unfortunately, the data as published are highly aggregate and do not reveal typical sequences. We shall return to this point below (see §4, page 18). In the interim, let us replace the dimension *type of accident* with *type of accident, event 1, type of accident, event 2,* and *type of accident, event 3.*[9]

It is a fairly straightforward matter to continue this line of reasoning and to arrive at a largely complete list of dimensions to represent existing or potential data. That list would include such dimensions as the following, among others (see [14, pages 3f]):

- Type of boat
- Hull material
- Engine

[9]Why stop at three? Why not permit an indefinitely long series of events to be recorded? Here, data representation theory should yield to practical considerations. Some small upper bound should be set with information in violation of it lost. For the present that number is 3.

- Wind
- Visibility

This translation effort at representation of the data in terms of independent dimensions does a a few additional complications, but these are rather easily handled. There are two main conditions to address. First, most of these data are categorical. The data are discrete rather than continuously measured, and the dimensional representation assumes this. Some of the data, however, are measured on a continuous scale, for example temperature and property damage. It is a straightforward matter to discretize these data into bins. For example, wind (none; light (0-6 mph); moderate (7-14 mph); ldots) is already treated this way.

The second problem or issue is that often the data categories are not mutually exlusive. For example:

- What in your opinion contributed to the accident? (Check all applicable)
  - Weather
  - Excessive Speed
  - No Proper Lookout
  - ...

(See "Boating Accident Report" form, [14, page 3].)

For present purposes, each of the non-exclusive items should be treated as a separate dimension. Typically, these dimensions will have just two possible values (yes/no). For example, we would have the following additional-separate and distinct—dimensions:

- Accident contribution from weather
- Accident contribution from excessive speed
- Accident contribution from no proper lookout
- ...

In short, all available data can be represented as independent diminsions consisting of discrete categories.[10] This is just the representation needed for the required crosstab (data cube) representation needed for purposes of analysis.

[10]We want to emphasize that this statement applies to structured data, not to (unstructure) textual information.

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