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Autor: Puglisi, Joseph J. / Riek, Justus R.

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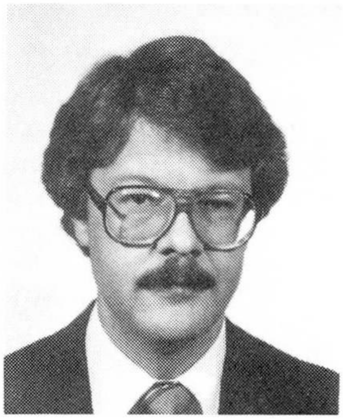
Offshore Structures and Navigation Risk Management
Constructions offshore et gestion des risques de navigation
Offshore-Bauten und Bewältigung von Navigationsrisiken

Joseph J. PUGLISI
Managing Director, CAORF
U.S. Maritime Administration
Kings Point, NY, USA

Justus R. RIEK
Mrg. of Res. and Experim.
CAORF
Kings Point, NY, USA

Joseph J. Puglisi, born in 1944, received his Masters Degree in Electronic Engineering and Computer Science from New York University and completed post graduate work in a Doctoral Program from Brooklyn Polytechnic Institute. For 12 years since 1970, he has directed projects in computer simulation, electronic navigation and communications at CAORF and the National Maritime Research Center, Kings Point, New York.



Dr. Riek, born in 1943, graduated from the University of North Carolina at Chapel Hill and spent 4 years in the U.S. Air Force as a meteorologist. He received his Ph.D. in Computer Science from Syracuse University in 1974 and joined CAORF. He is currently in charge of all research and operations activities.

SUMMARY
As oil drilling activities intensify in the coastal waters of the world, the potential for interference with merchant vessel traffic increases. The U.S. Maritime Administration, Office of Research and Development, has developed a comprehensive guide to marine risk management which is described briefly. Finally, a description is given of a specific risk management project, utilizing the Computer Aided Operations Research Facility (CAORF), to investigate the interactive effects of ship traffic and oil drilling activities of the Santa Barbara Channel in California.

RÉSUMÉ
Avec l'intensification des activités de forage de puits de pétrole dans les mers littorales dans le monde entier s'accroît la possibilité d'interférence avec le trafic de la flotte commerciale. L'administration américaine de la marine marchande a élaboré une instruction détaillée sur la gestion de risques de navigation: celle-ci est brièvement décrite. Un projet spécial de gestion de risques, à l'aide de l'ordinateur, est présenté pour le cas du forage de puits de pétrole dans le canal Santa Barbara en Californie.

ZUSAMMENFASSUNG
Gleichzeitig mit der Intensivierung der Oelbohrungsaktivitäten in den Künstengewässern der ganzen Welt, nimmt die Möglichkeit eines Eingriffes in den Handelsverkehr zu. Die Schifffahrt-Verwaltung der USA, hat eine umfassende Anleitung zur Bewältigung der Navigationsrisiken ausgearbeitet, welche kurz beschrieben wird. Abschliessend folgt eine Beschreibung eines besonderen Projekts zur Bewältigung von Risiken, in dem der Computer dafür verwendet worden ist, die Auswirkungen der Oelbohrungsaktivitäten auf den Schiffsverkehr des Santa Barbara Kanals in Kalifornien zu untersuchen.

1. INTRODUCTION

Political and economic forces continue to place pressure on society to permit development of offshore energy resources. There is no longer any real question about whether to permit such development, but only how much and under what conditions. Questions about energy development raise obvious questions of risk acceptance. Thus, the search for oil/gas in the oceans of the world is becoming very much concerned with risk management.

In recognition of this fact, the U.S. Maritime Administration has developed a general strategy for dealing with risk in a marine environment. This paper will discuss some of the more salient aspects of risk management, and give a brief description of the Maritime Administration approach. Finally, we shall present the more important results of a risk management project conducted for the state of California which studied the interactive effects of offshore drilling activities and merchant ship traffic, utilizing the CAORF simulator.

2. MARITIME RISK MANAGEMENT

As technology has advanced in sophistication and magnitude of consequences, people have become more interested in formal risk management. The public has taken a greater interest in those activities (eg. the LNG terminal) which are likely to affect their quality of life. Government, responsive to the demands of an aroused public, has begun to require that more comprehensive planning (eg. Environmental Impact Statements) take place in order to insure that tragic "surprises" do not occur. Private industry, with ships costing $100 million, is keenly interested in protecting that investment from all forms of risk. Everyone is interested in risk management. Encouraged by legislation in the form of Port Safety and Tank Vessel Safety Act of 1978, the National Maritime Research Center has moved to formalize this interest in the area of maritime risk [1].

The Port Safety and Tank Vessel Safety Act of 1978 directly addresses the requirements for a comprehensive management and mitigation program for marine hazards and risks. There are, however, strong guidelines as to what should constitute the basic tools to be employed in such a risk management program. Since human error accounts for a large percentage of marine accidents, the U.S. Coast Guard has not seen fit to rely on mathematical models for rule making. In considering the merits of probabilistic safety analysis, the U.S. Coast Guard is on public record that such an approach is not a sufficient basis for the specification of maritime safety procedures. Given the strong deterministic requirements of the above Act, it was natural for an agency such as the Maritime Administration to specify a set of guidelines for the conduct of risk management using as its primary analytical tool, the Computer Aided Operations Research Facility (CAORF).

CAORF is a sophisticated ship simulator which has become increasingly involved in marine transportation risk management relating to energy development. Intensive application of simulation techniques to investigate the human element in shipping has provided answers to questions involving LNG terminal siting, offshore energy development, tanker safety, and the modification of shipping patterns in response to port/terminal development. These investigations have developed reliable information in support of Environmental Impact Statements and helped define safe operating plans for energy-related terminals and ships.

It is important that simulation of the total environment surrounding the deck watch officer occur. Thus far, numerical modeling of the complex interactions between man-ship-environment using digital simulation has proved inadequate. From a mathematical point of view, human performance modeling with its complex feedback control loops has proved to be an intractable problem, producing incomplete and often erroneous results. While other forms of study may provide valuable insight into various restricted aspects of problems and solutions, the ultimate test of validity (short of the real world) is the simulation of problems in a realistic and controlled environment in which all important variables can be systematically manipulated to observe the effect upon human performance.

2.1 Maritime Risk Management Procedures

It is important to point out that the word "risk" is used here in a somewhat restricted sense. Risk management refers to the identification and mitigation of risks of physical damage to life, property or the environment which may occur as a result of marine casualty or the cumulative result of normal marine operations. Because the definition of what is "valued" can vary both as a function circumstance and point of view, it is the responsibility of various user agencies to translate the risks of such physical damage into "dollar values" or a degradation of the "quality of life." Even if such translation into objective utility is not entirely practical, the performance of these risk identification and mitigation efforts are useful in a relative sense, to order different situations/consequences as to relative risks and relative costs/benefits.

2.1.1 Approach

Despite the breadth and number of different aspects in a comprehensive maritime risk management program, a structured approach can be defined and may be applied in whole or in part to any marine project. Such projects may range from the establishment of a new route for shipment of a particular cargo to the construction of an entire port facility. Situations requiring risk management measures may vary from the effect of a single offshore oil drilling platform to the establishment of a Vessel Traffic Service in a busy harbor. In accordance with the basic concepts of risk management, all risks can be categorized into the three basic groups of risks to people, risks to equipment and risks to the environment. The overall risk management program approach involves three steps:

(1) Definition of applicable risk areas – in this step, the identification and categorization of potential risk areas associated with a maritime project leads directly to a structure for the risk management program required.
(2) Application of appropriate risk analysis techniques – for each risk area, appropriate risk analysis approaches are applied for the purpose of quantifying the risks and investigating appropriate risk mitigation measures. Techniques other than CAORF simulation are used as a form of supplemental analysis.
(3) Determination of applicable risk mitigation measures – this consists of the definition of vessel or facility design factors, hardware added, or procedures specified for the management or mitigation of the associated risks.

We shall discuss each of these three steps in more detail.

2.1.2 Risk Categories and Program Structure

The identification and categorization of risk areas associated with any project are the initial steps which must be taken for the purpose of establishing a risk management program. One simply creates a comprehensive list and then decides which are to be retained and which are to be disgarded. In many cases, the establishment of an Advisory Group to oversee the progress of the risk management project is an effective step. The Advisory Group should be made up of representatives of all the different groups which have an interest in the program. The Group can be especially helpful in the beginning by participating in the categorization of areas of risk and establishing the program structure. Such participation by a representative Group will help insure the completeness of the risks to be studied and will minimize the disruption which may occur later on if special interests attempt to modify the scope of the project underway. By involving people at the beginning and allowing them to help shape the program, acceptance of the risk mitigating measures will be facilitated. When the final recommendations are made, there will be no "surprises" on the part of regulatory agencies, public groups or commercial interests. The Advisory Group can also provide a forum in which communication between different special interest groups can resolve disagreements which might otherwise threaten the ultimate goals of the risk management program.

To get one started, the following very general risk categorization is recommended. The final list of categories will, of course, be a function of the specific project under consideration and the resources to accomplish the study.

- I. Risks to life
  - A. Project personnel
    - 1. Shipboard
    - 2. Facility operating or related support
  - B. Public
    - 1. Residents
    - 2. Traffic or other transient
    - 3. Visitor or recreational
      - a. Land (beaches)
      - b. Boating (pleasure/fishing)
- II. Risks to property
  - A. Ownship
    - 1. Internal
    - 2. Interaction with other vessels
  - B. Other vessels (project related vessels)

- C. Terminal
  1. Onshore components
  2. Offshore components
- D. Other facilities
  1. Public
  2. Industrial

III. Risks to marine environment
- A. Terrestrial – damage from casualty
- B. Oceanographic
  1. Oil spill
  2. Chemical release
  3. Creation of navigation hazard
- C. Atmospheric
  1. Emissions
  2. Chemical release
- D. Long term environmental impact
  1. Normal operations
  2. Casualty occurrence

Finally, this first step of the risk program development should also include
– a review/evaluation of existing agency authorities, legislation and regulation
– a study of available and in-place mitigation measures and resources for prevention and containment of potential casualties
– an evaluation of existing contingency and response plans/procedures.

2.1.3 Analysis Approaches and Methodologies

In examining and quantifying the various types of risks in a maritime risk management program, a number of types of analysis are necessary. To carry out these types of analysis, various analytical techniques may be applied. Six basic types of analysis which are applicable in a comprehensive maritime risk management program are briefly described below. Further information on each may be found in [1].

(1) Personnel and Public Risk Exposure Analysis.
The object of this analysis is to define the type and levels of risks to which maritime project personnel and the general public are exposed due to the presence or operation of the maritime project. It requires a description of the vessel, facility or operation in the preliminary design stage, a description of operating procedures and a description of planned safety/containment features. The primary output from this type of analysis will be
– contingency procedures
– safety/emergency equipment
– monitoring, detection or warning systems
– vessel or facility design factors such as fire prevention, retarding or fighting systems, escape routes, etc.

(2) Simulation Analysis.
Simulation is generally performed in one of two ways – a) using fast-time digital computers solving hydrodynamic equations of motion to drive ship models under the control of various types of autopilots b) using the CAORF simulator to conduct elaborate investigations into the relevant aspects of human performance. Fast-time simulation may be useful for the study of less critical problems in which a high degree of fidelity is not required, or as a screening device to perform a preliminary assessment of risk inherent in problem situations before placing those most critical on the CAORF simulator for a more comprehensive investigation.

(3) Casualty Analysis.
The object of this type of analysis is to investigate the cause and effect relationship in a set of casualty scenarios postulated as feasible in the marine operation under consideration. For ship operations the initial types of vessel casualties ordinarily postulated are
– internal system failure
– fire/explosion
– grounding
– ramming
– collision

Generally conducted in the form of a fault-tree analysis, the chief output of this analysis is the development of a broad spectrum of potential casualties together with their probable cause and effects. See [2] for an elaborate example of such a procedure in a maritime setting.

(4) Safeguard Analysis.
This deals with human deliberate actions to damage or destroy important marine assets. Its primary objectives are to
- evaluate susceptibility to sabotage
- estimate consequences
- recommend countermeasures

Most maritime projects already in existence will not have been designed to cope with any well organized threat. Maximum protection to such facilities may be limited to added hardware or procedures since the basic design factors are already in place. The key to the procedure is "threat definition." New facilities of a critical nature can be "hardened" during the design phase to minimize the risk due to identified threats. The analysis will depend upon the nature and criticality of the maritime project under consideration. Some of the more obvious mitigation measures will likely include
- physical barriers
- area and underwater surveillance devices
- specialized communication systems
- security escorts for ships
- traffic control
- damage control equipment
- personnel screening
- visitor clearance and control
- guard training/use of weapons

(5) Salvage Analysis.
Salvage analysis proceeds from the delineation of one or more casualty scenarios. The object of the scenario definition and analysis is to identify potential casualty outcomes and the associated requirements for contingency planning, salvage actions, equipment, personnel and their training.

(6) Environmental Effects Analysis.
The purpose of this analysis is to quantify the effects of maritime operations on the terrestrial, oceanographic and atmospheric environment in both the short-term and long-term.

2.1.4 Mitigation Measures

The essential product of any maritime risk management program is to create a list of mitigation measures to be applied as appropriate to eliminate or minimize physical hazards. All candidate measures will fall into one of the three categories of design, hardware or procedures. While the specific measures resulting are likely to be a function of the nature of the project evaluated, the types of risks considered and the nature of the analyses applied, a general listing of likely mitigating measures can be given. These would include
- requirements for specific navigation, communication and safety equipment
- control of vessel movement
- determination of port, port access and vessel operating procedures
- designation of fairways and traffic separation schemes
- definition of hazardous cargo handling procedures
- establishment of safety zones
- establishment of pilotage, manning and training standards
- regulation of vessel design factors

3. SANTA BARBARA CHANNEL RISK MANAGEMENT PROGRAM

Oil and gas reserves are known to exist under the Santa Barbara Channel off the coast of southern California. This risk management program was conducted to determine means to minimize risks to facilities and the environment resulting from offshore oil and gas recovery activities. Since the entire project is described in detail in [3], we shall present only a brief description of many of the more routine aspects of the investigation.

3.1 Advisory Groups

An Advisory Group was formed to guide the work on the project. It included representatives from the U.S. Coast Guard, local shipping associations, oil companies, environmental groups and project personnel from CAORF and the California Coastal Commission for whom the program was being conducted. The participation by the Coast Guard was deemed particularly important in view of the probable regulatory implications of program recommendations. With the Coast Guard in the Group, the facilitation of rule making was thought to be enhanced.

3.2 Background Data

Worldwide and nationwide vessel and offshore oil development casualty data were assembled. The data indicate that vessel to vessel collisions, ramming of offshore structures and on-board vessel casualties are the primary risk areas. Worldwide, vessel groundings are a problem, but the nature of the Santa Barbara Channel minimizes the probability of this risk. Of all collisions, rammings and groundings, 78 percent have occurred either at night or under conditions of limited visibility. Human error, due to inattention or to circumstances requiring decision and action out of the ordinary, was found to be the cause of the vast majority of casualties.

Finally, environmental data for the channel were assembled to permit selection of realistic wind, current and visibility conditions in the course of subsequent analysis.

3.3 Vessel Traffic and Oil/Gas Development Projections

To establish the likely levels of both vessel traffic and offshore drilling activities, projections were completed in both areas. Based upon west coast port activity and commodity flow projections as well as probable growth in ship sizes, vessel traffic through the channel has been projected from the current total of 25 ships per day to a nominal of 29 and a maximum of 43 ships per day by the year 2000. Thus, one of the basic assumptions under which this study was conducted is that there will be no dramatic increase in the flow of merchant ship traffic through the Santa Barbara Channel during the next 10-20 years.

Using information from the Department of the Interior Lease Sales and the state-of-the-art in oil drilling, areas and densities of likely drilling, construction and production have been projected through the year 2000. By that time, the nominal number of new platforms in production in the channel will be 29, with the maximum number projected at 47. Due to the locations of potential oil reserves, there are numerous desirable locations for exploratory drilling and production platforms near or within the Traffic Separation Scheme.

3.4 Potentially Applicable Risk Management Measures

There are a number of risk mitigation measures currently in effect in the Santa Barbara Channel. Primary among these is the passive Vessel Traffic Separation Scheme (VTSS). U.S. Coast Guard surveys have shown that compliance with the voluntary VTSS is virtually 100 percent for merchant ships transiting the Channel. Numerous other risk mitigation measures are possible, ranging from additional safety fairways to a positive vessel traffic position monitoring system and active Vessel Traffic Service (VTS) by the U.S. Coast Guard. However, it was one of the basic assumptions of this study that the VTSS would remain in its present location with no modifications to its existing geometry.

A detailed discussion of existing and potentially applicable risk management measures is contained in [3]. It is from this spectrum of choices that the recommended Channel risk management measures have been selected. In particular, constraints are recommended on the placement of temporary or permanent structures proximate to paths of vessel traffic.

3.5 Generation of Risk Exposure Scenarios

Based on the oil-related development and vessel traffic projections described above, a number of situations were developed representing conditions of vessel/structure exposure to hazard. These situations formed the basis for the analytical and simulation experimental work carried out, and are:

1. Drilling rigs (or ships) in or near the Traffic Separation Scheme (TSS).
2. Production platforms near the TSS.
3. Production platforms or drilling rigs in the separation zone.
4. Platforms/rigs near the TSS dogleg.
5. Platforms/rigs near the safety fairway/TSS intersection(s).
6. Platforms/rigs at northern end of TSS.
7. Vessel navigation accuracy while transiting the Channel.
8. Supply boat, crew boat, barge traffic in all areas.

These situations were synthesized into a number of scenarios, which were then subjected to analysis and simulation.

3.6 CAORF Simulation

A total of thirteen (13) conditions was developed to examine the responses of the mariner (through his navigation of the vessel) to a variety of platform and drill ship siting configurations, and with regard to potential traffic encounters in the Santa Barbara Channel. The scenarios occurred in a part of the Santa Barbara Channel approximately 15 miles in length, between the mainland and the channel islands, and centered about Port Hueneme, California.

The data base was divided into two segments, one starting 4.5 miles south of the Port Hueneme Access Fairway, extending to the turn axis of the TSS on a course of 300°T along the northbound traffic lane (Segment A). The second segment (Segment B) started at the turn axis and extended along the 285°T leg of the northbound traffic lane to a point 5 miles beyond the turn axis (Figure 1).

A total of four conditions were presented in Segment A and nine in Segment B. One condition in each segment (A1 and B1) served as a baseline run to assess individual trackkeeping performance in the absence of the interactive traffic vessels or obstructions near the northbound traffic lane.

Mariner responses to various small vessel traffic in and about the traffic lanes and interactive ship traffic at the lane's intersection with the access fairway at Port Hueneme were the subject of Segment A runs under three conditions (Figure 2). In addition to the traffic, two scenarios included the presence of fixed platform in the separation Zone near the fairway intersection, the position of which was known by the subject and plotted on the chart. Segment A scenarios were run in daylight with a three mile visibility range.

The nine conditions in Segment B were all run in daylight with restricted visibility (0.5 mile). The visibility conditions imposed are not uncommon for the area. Eight of the nine conditions in the B Segment investigated the response of ship masters to different configurations for stationary drill vessels alone and in conjunction with fixed platforms, near to or straddling the traffic lanes (Figure 3). A worst case condition was investigated where visibility was poor and subjects had no foreknowledge of drilling vessel and platform positions. Because of the imposed visibility condition, the vessel's radar was heavily relied upon. In order to prevent subjects from taking a complacent attitude after a few runs to the stationary targets representing platforms and drilling rigs, a number of additional vessels were included in each scenario so that no immediately discernable pattern would be displayed on the radar PPI. A variety of chaff vessels including other ship traffic, fishing boats, and support craft such as crew boats, supply boats, tugs and barges, etc., performed different maneuvers so that plotting of all echoes became necessary in order to distinguish slowly maneuvering vessels from stationary targets.

Wind, current and visibility conditions were comparable to actual local conditions during late Summer/early Fall. Wind was input as westerly at 15 knots and the current was about 0.5 knot setting 090°T. The reduced visibility conditions differed by scenario segment and were described previously.

The two vessel types simulated for ownship were an 80,000 DWT tanker and a 12,000 GRT containership, to be operated by 10 tanker and 10 containership masters in each category respectively.

The CAORF bridge contained the same equipment regardless of the ship type simulated. A full array of control and monitoring equipment as well as navigation aids was made available to the test subjects. In particular, two functioning radars were available for navigation and collision avoidance problem solving. These equipments were strongly relied upon in the reduced visibility conditions which were imposed.

All conditions which were presented required the master to be conning the vessel due to the reduced visibility and the presence of traffic, particularly the increased density of vessel traffic in the approaches to Port Hueneme. The master in each case was assisted on the bridge by the Watch Officer, a qualified and licensed second or third mate. A helmsman was provided and steering was in the manual mode. While the Watch Officer performed duties assigned by the master, he was instructed not to volunteer any information unless it pertained to the assigned duty (such as the master requiring him to call out range and bearing to all radar contacts). The master was required to make all decisions based on the information available and without consultation with the Watch Officer.

The same conditions were presented to both groups of masters in a random order. To compensate for differences in speed between the tanker and the container vessel, (15.5 knots for the tanker and 19.3 knots for the containership) start positions and timing of the programmed interactive traffic vessels (no more than two vessels in any condition) were adjusted.

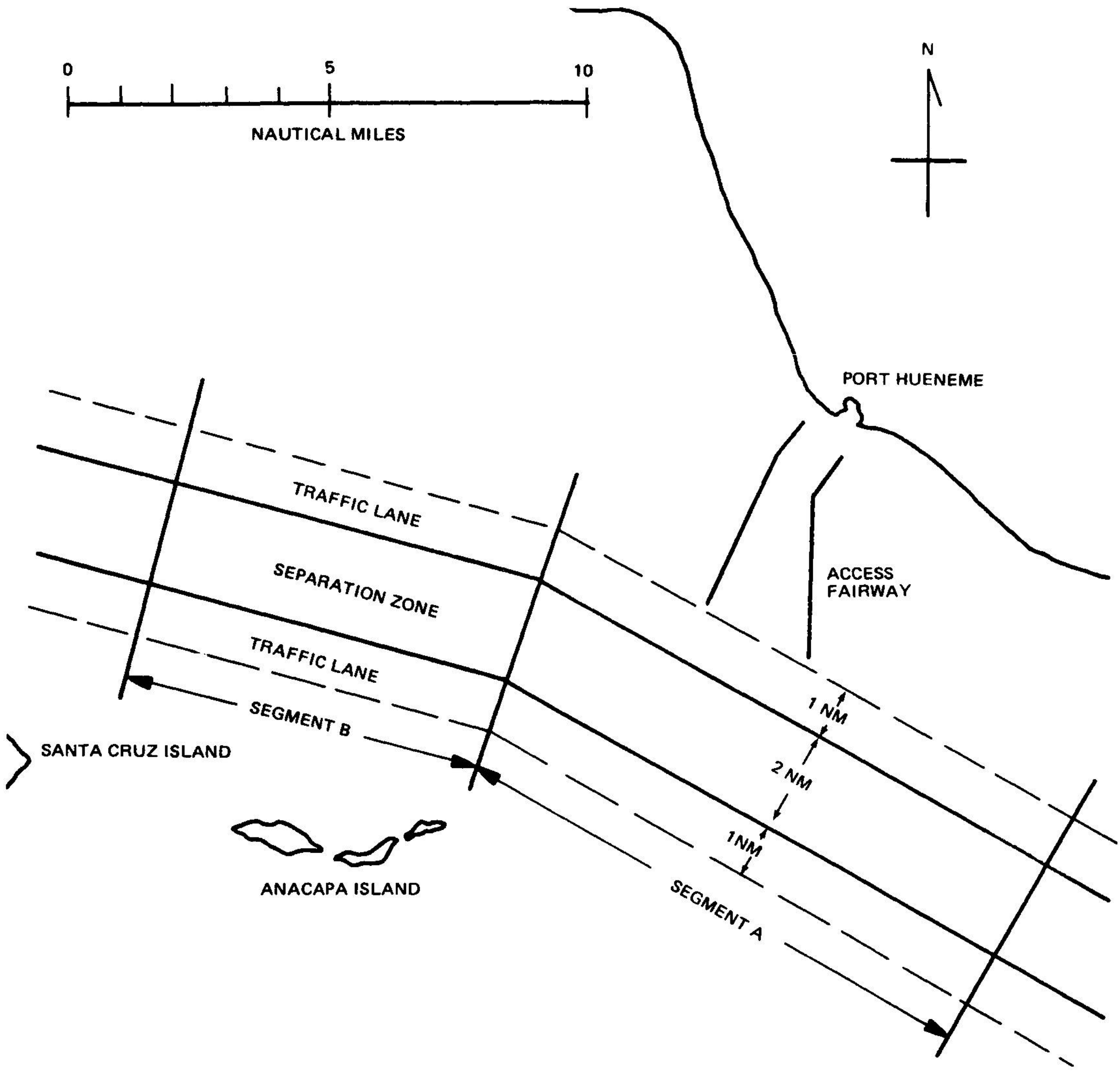


Figure 1. The Santa Barbara Channel Traffic Separation Scheme
Showing Segments A and B Used to Develop Various Simulation Scenarios

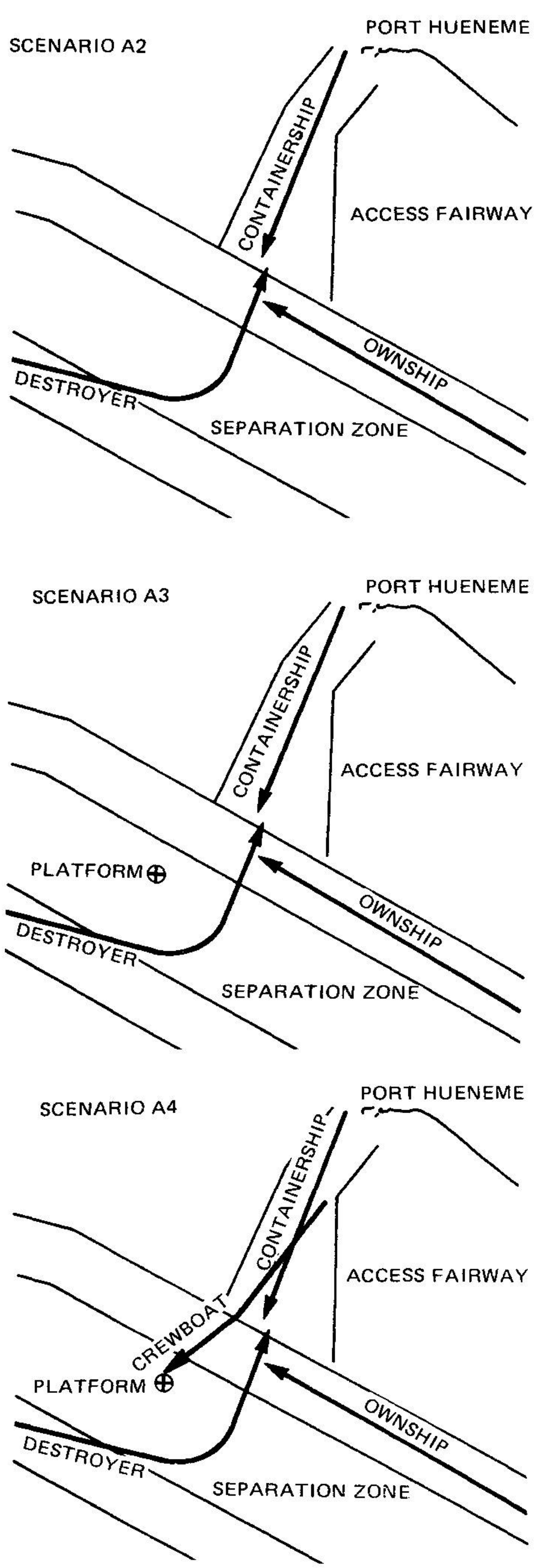


Figure 2. Segment A Scenarios Showing Three/ Platform Configurations About the Traffic Lanes and Access Fairway. Chaff Traffic Not Detected.

3.7 Results and Recommendations

The man-in-the-loop simulation conducted involved two generic problems to be encountered in the Santa Barbara Channel. They were:

- The effects on merchant ship traffic of stationary drill rigs and platforms near the edge of the traffic lane.
- The effects on merchant ship traffic of other crossing traffic in the vicinity of a safety fairway intersecting the traffic lane.

Stationary Drill Ships/Rigs Near the Traffic Lane

The experiments conducted with a single stationary drill ship near the edge of the traffic lane indicated that ship masters definitely reacted to the presence of the drill ship (Tables 1 and 2). The evasive maneuvers of test subjects ranged from small maneuvers to maneuvers out of the traffic lane on the side opposite the stationary drill ship. In general, maneuvers were smaller with the drill ship set back 500 meters from the edge of the traffic lane than with the drill ship located at the edge of the traffic lane.

Additional experiments were conducted with the drill ship and a platform located opposite one another at the edges of the traffic lane, forming a "gate." Faced with the prospect of either leaving the traffic lane to go around the gate, or navigating through the gate, most masters remained in the lane and sailed through the gate. Navigation performance as well as post-experimental debriefings indicate, however, that many did so with reluctance.

Subsequent experimental runs were made in which the opposing rig of the above gated configuration was moved down the lane a distance of 1 and 2 nautical miles to form staggered gates. The responses of the test subjects were more variable in these situations than in either of the single drill ship or gated configurations, especially on the part of the tanker masters. Several test subjects left the lane completely to avoid the situation and there was a significant difference between the containership and tanker master performance. Containership masters tended to sail down the center of the lane with little or no deviation. Tanker masters were more likely to perform a slalom type of maneuver, moving right away from the drill ship and then to the left away from the subsequent rig. This slalom maneuver was more pronounced in the tanker master group with the 2 mile staggered configuration.

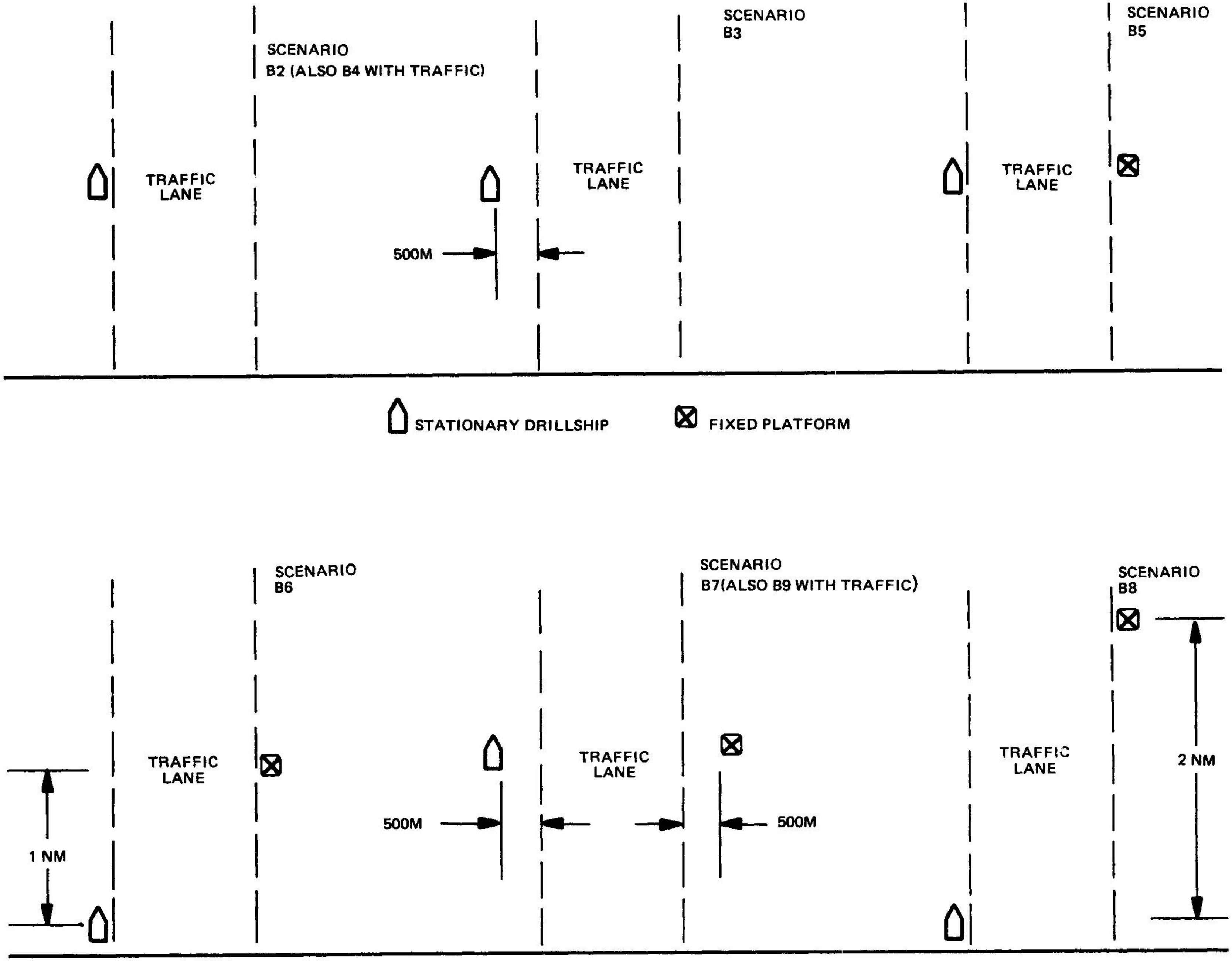


Figure 3. Segment B Scenarios Showing Various Drill Ship/Platform Configurations About the Traffic Lane (Dashed Lines)

TABLE 1. TEST SUBJECT MANEUVERING RESPONSES IN SCENARIOS B1, B2, B3, AND B4

	B1				B2				B3				B4			
Group	R	RS	R/RS	MCS	R	RS	R/RS	MCS	R	RS	R/RS	MCS	R	RS	R/RS	MCS
Tanker	0	1	0	9	5	0	3	2	3	2	1	4	6	0	3	1
Containership	0	0	1	9	8	0	0	2	3	1	0	6	7	0	3	0
Total	0	1	1	18	13	0	3	4	6	3	1	10	13	0	6	1

R = Right turn.
RS = Speed reduction.
R/RS = Right turn in conjunction with speed reduction.
MCS = Maintain course and speed.

AVERAGE MAXIMUM DEVIATION FOR SCENARIOS B2, B3, AND B4

	Tanker Masters				Containership Masters				All Masters			
	B1	B2	B3	B4	B1	B2	B3	B4	B1	B2	B3	B4
Average Maximum Deviation (n.m.)	0.04	0.25	0.16	0.30	0.04	0.34	0.14	0.36	0.04	0.30	0.15	0.33
Standard Deviation (n.m.)	0.04	0.18	0.21	0.25	0.05	0.33	0.15	0.13	0.04	0.26	0.18	0.20

Cross Traffic Encounters at Fairway Intersections

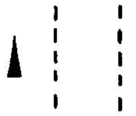
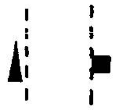
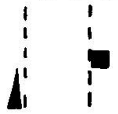
This part of the simulation experiment presented the test subjects with vessel traffic of a crossing nature, encountered while ownship was navigated within the lanes of a Traffic Separation Scheme (TSS). The problem simulated for the mariners took place at an intersection of a Port Access Fairway with the traffic lanes at Port Hueneme, California.

Conditions which co-existed with the traffic encounter problem included the presence or absence of a fixed structure within the TSS (a production platform), and varying levels of small craft such as resource recovery support vessels.

The results of these simulation runs showed a variety of responses to the crossing traffic problem which are independent of the restriction/workload conditions. More tanker masters than containership masters departed the traffic lanes in executing their avoidance maneuvers and reduction of speed was a prominent characteristic of the former group (Figure 4). Although these out-of-lane deviations were made with little hesitation in order to comply with the collision regulations, the higher frequency of occurrence within the tanker group is consistent with the maneuvering characteristics inherent in large tankers versus the capabilities of the fine-lined, high speed containership. The tendency among the tanker masters to reduce speed initially indicates a more conservative reaction to the traffic problem.

The siting of a stationary object in the Separation Zone, either alone or in conjunction with additional small vessel traffic, did not appear to influence the maneuvering decisions. These conditions were apparently assigned a priority which was secondary to the maneuvering requirements with respect to the capital ships present. Likewise the subjects' individual criteria for acceptable passing distances to other vessels, and their perceived obligations under the International Regulations for Preventing Collisions at Sea (COLREGS '72) in a crossing situation, took precedence over the exhibited desire to remain within the confines of the traffic lanes.

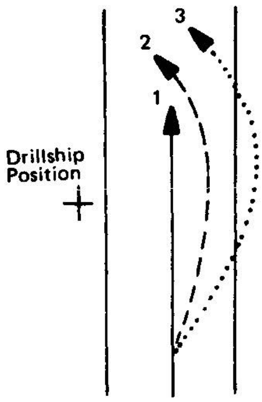
TABLE 2. COMPARISON OF THE PERFORMANCE CHARACTERISTICS EXHIBITED BY SUBJECTS IN RESPONSE TO EACH OF THE CONFIGURATIONS PRESENTED IN SEGMENT B SCENARIOS

Drill Ship/Platform Configurations	Scenario	Subject Group	Performance Characteristic (No. of Subjects)			Subjects per Group
			↗ (solid)	↗ (dashed)	↗ (dotted)	
	B2	T	2	7	1	10
		C	2	6	2	10
	B3	T	6	3	1	10
		C	7	3	–	10
	B5	T	5	1	–	6
		C	6	–	–	6
	B7	T	5	–	1	6
		C	6	–	–	6
	B6	T	2	2	2	6
		C	6	–	–	6
	B8	T	1	4	1	6
		C	5	–	1	6

SUBJECT GROUP CODE

T = Tanker

C = Containership



Comparison of the performance characteristics exhibited by subjects in response to each of the configurations presented in Segment B Scenarios.

Recommendations

1) No structures, whether of a permanent or temporary nature, should be permitted to be situated in the traffic lane of a TSS nor within a Safety Fairway. This should include stationary drill ships and drilling rigs engaged in exploratory operations. In particular, the idea of moving the traffic lanes on a temporary basis to accommodate such drilling activities is not recommended. The logistics involved in effectively communicating such a lane change to the worldwide marine community are substantial, and it is unlikely that complete dissemination of information could occur in any short period of time. The negative implications for safety are obvious.

2) Permanent structures should not be sited within 500 meters of the boundary of a Traffic Separation Scheme lane in order to maintain the integrity of the established lane-width. The erection of two structures on opposite sides of a traffic lane so as to form a "gated" configuration should not be permitted if either structure would be sited within 1000 meters of the closest lane boundary. If a permanent structure is positioned within 1000 meters of the nearest lane boundary (but not closer than 500 meters in any case) no structure should be permitted to be erected on the opposite side of the traffic lane within 1000 meters of the opposite boundary for a distance of at least two nautical miles in either direction along the lane from the initial structure.

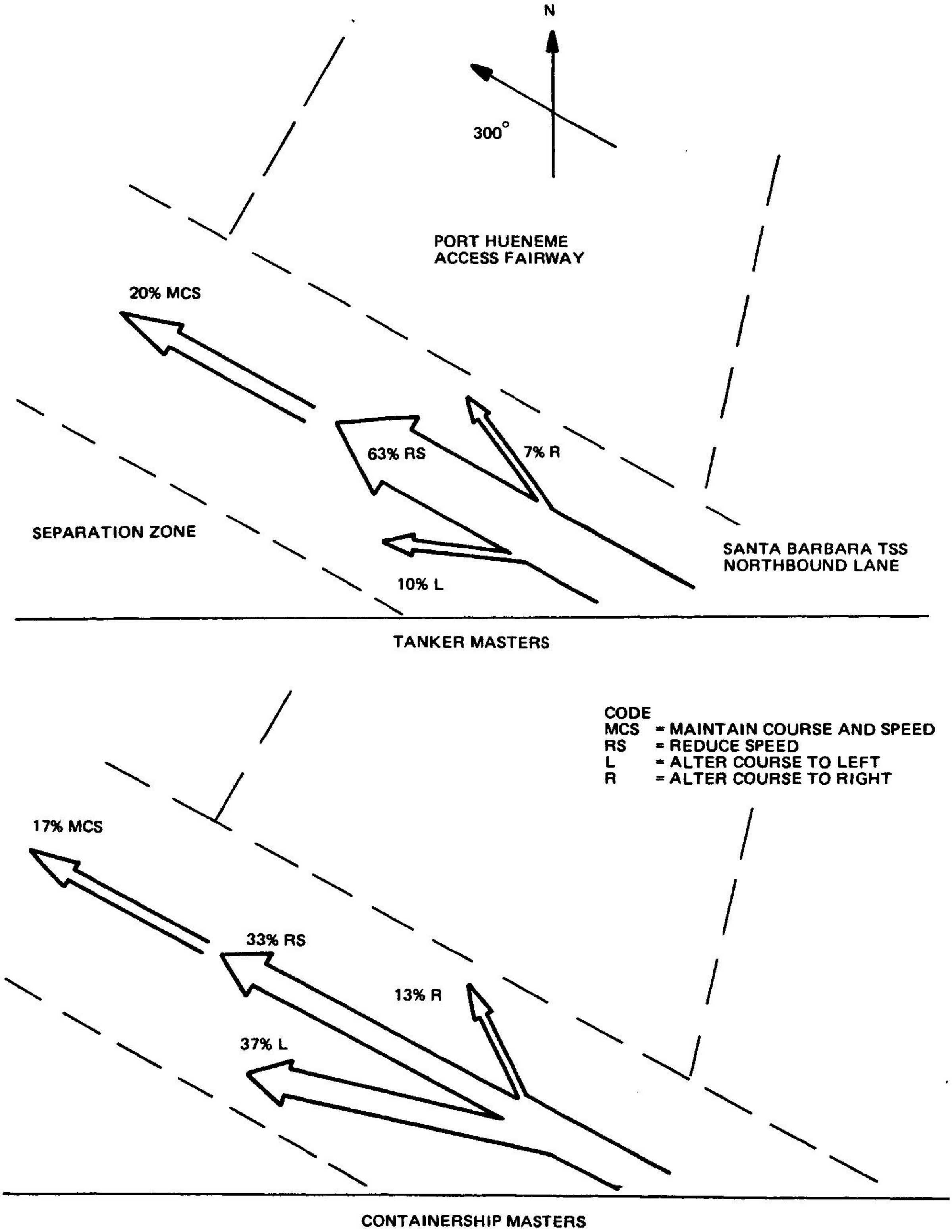


Figure 4. Graphic Presentation of the Distribution of Initial Commands in Response to the Collision Avoidance Problem in Scenarios A2 - A4

3) The presence of even temporary structures (e.g., drill ships, drilling rigs, or other resource recovery-related obstacles) within 500 meters of the traffic lane poses some threat. While the mitigation measures can be devised to reduce this threat, there is not adequate information at this time to conclude that it would be reduced to an acceptable level.

4) No temporary or permanent obstructions, including platforms, drilling rigs, and drill ships should be permitted to be erected or to operate within the extension of an intersecting Safety Fairway through the TSS traffic lanes or Separation Zone, nor within 1000 meters of the traffic lane boundaries and extension boundaries at the intersection.

5) A marshalling or designated waiting area should be defined during the construction of pipelines or erection of any structure where tug/barge units or other support craft involved in the operation will impact the users of the traffic lanes. Such marshalling areas should be situated well clear of the Traffic Separation Scheme, Safety Fairways, and normal approach routes utilized by tankers enroute to coastal terminals, and will serve to consolidate slow moving small craft away from the shipping routes. It will also minimize the number of points at which the traffic lanes would be crossed by these craft enroute to the construction site.

REFERENCES

1. Maritime Risk Management Procedures, National Maritime Research Center, 1979.
2. FARAGER, W.E. et al., Deepwater Ports Approach/Exit Hazard and Risk Assessment, United States Coast Guard Report No. CG-D-6-79, 1979.
3. Santa Barbara Channel Risk Management Program, National Maritime Research Center, Report No. CAORF 24-8015-01, 1981.