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Research Methods to Develop Measures of Effectiveness of the United States Coast Guard's Vessel Inspection and Boarding Program, Volume 1 – Executive Summary

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**Research Methods to Develop Measures of Effectiveness of the United States Coast Guard's
Vessel Inspection and Boarding Program, Volume 1 - Executive Summary**

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Abstract

The primary objective of this study is to provide Measures of Effectiveness (MOEs) of the U.S. Coast Guard Marine Inspection and Boarding Program based on objective scientific methods. A secondary objective of the study is to provide USCG management with a methodologically and theoretically sound aid to effective policy decision-making. The MOEs constructed in this study are specific to the Marine Inspection and Boarding Program, but the methodology of the study is based on sound theoretical principles that are probably applicable to a range of USCG activities. Hence the methodology applies equally to other important USCG programs and can be similarly used to measure their effectiveness and as an aid to decision-making.

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E.1 Introduction

The primary objective of this study is to provide Measures of Effectiveness (MOEs) of the U.S. Coast Guard Marine Inspection and Boarding Program based on objective scientific methods. A secondary objective of the study is to provide USCG management with a methodologically and theoretically sound aid to effective policy decision-making. Although the measures of effectiveness constructed in this study are specific to the Marine Inspection and Boarding Program, the methodology of the study is based on sound theoretical principles that are probably applicable to a range of USCG activities. Hence the methodology applies equally to other important USCG programs and can be similarly used to measure their effectiveness and as an aid to decision-making.

Measures of effectiveness are provided at three levels: an overall, Program-wide level (Level I), a major activity level (Level II), and a more disaggregated sub-activity level (Level III). Level II activities cover major activities including Certificate of Inspections, Reinspections, Hull Drydock Exams, and Foreign Flag Annual Vessel Examinations. Level III MOEs cover the principal components that make up a vessel inspection or boarding including sub-activities related to Cargo Handling, Pollution Control, Steering and Navigation, Document, Drills, Auxiliary Equipment Power Plant, Fire-Fighting, Hull, and Life Saving. Data pertaining to deep-draft vessel inspections and boardings from the Marine Safety Management System (MSMS) database provide the inputs in the construction of the MOEs.

Implementation of the results of the econometric analysis was done by using decision support system (DSS) technology. A DSS is an interactive, flexible and adaptable computer-based system that employs a model(s) to aid in problem solving and decision making. A key component of any DSS is the human-machine interface; it should allow the user to interact with the model(s) and display its results in an easy-to-understand format. The prototype DSS was developed for the USCG Office of Marine Safety on a PC workstation allowing graphical displays and interaction with the model(s) via a "spreadsheet" format, in Excel. The prototype DSS is presented in greater detail in a companion document, "Decision Support for Utilizing Measures of Effectiveness." In addition, a description is provided of how the measures of effectiveness could be integrated with a resource allocation methodology to support USCG Office of Marine Safety staff in budgeting, organizational redesign and other management activities.

E.2 Methodology

Two separate approaches, which complement each other nicely, are employed in this study. The first approach employs state-of-the-art econometric models in the analysis of a behavioral relationship between the *number of Personnel and Pollution casualties* and *resources expended* by the Marine Inspection and Boarding Program. The ensuing estimates directly provide measures of effectiveness of the Program by (i) quantifying the *decrease* in the expected number

of Personnel casualties (deaths, missing, injured) and Pollution casualties that result from an increase in the expenditure of such resources, and (ii) quantifying the *increase* in the duration-to-casualty resulting from an increase in resources. Graphical analysis to ensure integrity, and extensive sensitivity analyses to test for robustness of the econometric results are performed. The econometric models are employed to provide measures of effectiveness at the Program, Major activity, and Sub-activity levels. Measures of effectiveness from the econometric approach are broken down by (i) type of service, and (ii) type of flag. The second approach, called Risk-Based Ranking (RBR) [Wheeler (1993)], is used to enumerate the contribution of factors, which are targeted by Level III activities as being key contributors to the occurrence of casualties, to the risk of Personnel and Pollution casualties. The RBR constructs measures of importance for each Level III activity. Large importance measures underscore those activities that may be expected to offer the largest returns from concentrating resources in those areas. We provided risk-based rankings and importance measures broken down by (i) type of service, (ii) type of flag, and (iii) Marine Safety Office (MSO) and district. In addition to being stand-alone results, the risk-based rankings also critically supplement the results of the econometric analysis and provide valuable information in efficient decision-making based on the econometric results.

E.3 Inferences: Marine Inspection Program

From an analysis of 951 U.S. flag deep-draft vessels, the econometric estimates provide clear and strong evidence that the resources expended by the Marine Inspection Program are effective in reducing the expected number of deaths, injuries, and pollution incidents. At Level I, Table E.2 attests to the effectiveness of each type of resource hour expended – hours devoted to hull activities (Hull hours), hours devoted to machinery activities (Machinery hours), and hours devoted to administration activities (Administrative hours) – in reducing deaths, Table E.3 provides evidence of their effectiveness in reducing injuries especially on Freight ships and Tank ships, and the sharp results in Table E.4 attests to their effectiveness in reducing pollution occurrences, especially on Tank ships. The statistical significance of the results is all the more stronger if in interpreting the estimates presented we recognize that the primary objective of USCG inspections is to prevent events of great significance, such as deaths, serious injuries, and large oil spills. In statistical terms, we consider *t*-statistics greater than 1.00 in absolute value to be statistically significant in assessing effectiveness of the Program. By this standard, the last three columns in Table E.4 show that Hull, Machinery, and Administrative hours are each highly effective in reducing pollution occurrences on both Freight and Tank ships. From Table E.2, we see that Hull, Machinery, and Administrative hours are each highly effective in reducing personnel Deaths and Missing casualties, particularly in Passenger and Freight ships. From the estimates in these tables we can quantify the expected number of casualties that may be reduced by increasing resource hours. For example, the estimate of -1.167 in the first column of Table E.2 implies that the expected number of Deaths and Missing can be reduced by .03 (over a 3-year period) if Hull hours are increased by 1000 (over a 5 year period). The corresponding numbers for injury reduction using results from Table E.3 is .12 (over a 3-year period), and for

the reduction in pollution occurrences from Table E.4 is .29 (over a 3-year period).

At Level II we use the Duration model to infer how a change in the deployment of resource hours affects the *time to a Personnel or Pollution casualty*. This model is employed because Level II activities are naturally defined in terms of duration. For example, a Freight ship COI is required once every two years, Reinspections (Activity II.A.2) are required in alternate years, Hull Exams (Activity II.A.3) are required twice every five years with the requirement that not more than 3 years elapse between two inspections, and Annual Exams (Activity II.B.1-3) are required of Foreign flag vessels every year. Hence the effectiveness of these activities is best measured in how much longer they are able to prolong casualty-free operation of a vessel. Results from the duration analysis given that a Certificate of Inspection was performed, presented in Tables E.5 and E.6 shows Machinery hours and Administrative hours to be strongly effective in *increasing* time to Personnel casualty, particularly in Freight ships. If a 30% significance level is used ($t=1.00$) then each resource variable is effective in increasing time to Personnel casualty on vessels of almost all services. COI's are, however, not shown to be as clearly effective in prolonging Pollution casualties as they are for Personnel casualties, and only very weak inferences can be drawn on this count. Reinspections are clearly shown to prolong duration to Personnel casualties for all services in Table E.7, but the Pollution results in Table E.8 do not allow any inferences about the effectiveness of Reinspections in reducing pollution casualties aboard Freight ships and Tank ships. The results for Hull Exams in Tables E.9 and E.10 are strong and impressive. Hull hours, and indeed Administrative hours are effective in increasing time to Personnel casualty in vessels of all services, while Machinery hours is effective for Freight ships. Hull hours are particularly effective in reducing Pollution casualties on Freight ships and Passenger ships. Clearly Hull Exams successfully achieve their safety goals in increasing time to Personnel as well as Pollution casualties.

At Level III the results are impressive and strongly attest to the effectiveness of each Level III activity in reducing Personnel and Pollution casualty. A Poisson model of casualties, similar to those employed in assessing Level I effectiveness of Marine inspection of U.S. deep-draft vessels is employed here. Hours devoted to Cargo Handling/Pollution Control is certainly effective in controlling pollution occurrences as evidenced by the results in Table E.11. Results for other Level III activities in Tables E.12-E.17 indicate a great degree of success in controlling pollution and personnel casualties.

E.4 Inferences: Foreign Vessel Boarding Program

The results from an analysis of 10904 Foreign flag deep-draft vessels are not as strong and unambiguous as those for U.S. flag deep-draft vessels. The number of Foreign flag deep-draft vessels examined by the USCG far outnumbers the number of U.S. flag deep-draft vessels. But whereas U.S. flag vessels are subject to inspection requirements laid down by the USCG, and hence are subject to thorough safety checks, this is not always true of Foreign flag vessels. The desired outcome of USCG inspections with respect to Foreign flag vessels is to minimize Personnel and Pollution casualties *in U.S. waters*, whereas the objective with regard to U.S. flag vessels is to minimize casualties *anywhere*. Does the USCG Boarding Program successfully

achieve this objective ? If so, is there evidence that the USCG achieves this efficiently ? The first question can be answered unconditionally, simply by observing the number of Personnel and Pollution casualties that have occurred since 1991. Between 1991 and 1993 there were 61 Deaths and Missing, 97 Injured, and 535 Pollution occurrences. Since well over 10000 deep-draft vessels were examined over these years the casualty rate is impressively low. Clearly, the USCG program of examining Foreign flag vessel is successful in achieving very low number of incidents with grave consequences such as deaths and missing and large pollution casualties in U.S. waters. The answer to the second question is not easy to obtain for two reasons. Compared to U.S. flag vessels, there is much more uncertainty about the state (i.e., condition) of a Foreign flag deep-draft vessel that enters U.S. waters than is the case for a U.S. flag deep-draft vessel. Foreign flag vessels are subject to widely varying degrees of monitoring and regulation depending of their flag, which can just as easily change from one port call to another. This makes the distribution of USCG resource hours in examining/monitoring a more complicated and fuzzy task than it is in the case of U.S flag vessels. We believe a complete analysis of the Foreign flag examination program must involve a deep examination of the nature of the monitoring/boarding problem. We feel that it may be possible to design a "contract" with Foreign flag vessels which enables the USCG to obtain better information about the state of the vessel on a "voluntary" basis. This is akin to insurance companies designing contracts in a manner that allows them to "voluntarily" obtain information about potential insureds. We feel that it is possible to design such an optimal contract that provides the proper incentives to Foreign flag vessels. According to the present system, the only incentive a foreign flag shipowner has to comply with USCG safety standards is a nominal monetary penalty. Hence the onus is entirely on the USCG to detect and correct problems on Foreign flag vessels. Naturally the use of USCG resources will not be as efficient as in the case where the Foreign flag shipowner "volunteers" correct information. The motivation for the study of optimal incentive contracts is two-fold. Firstly, the provision of better information pertaining to a Foreign flag vessel can significantly lower the resource expenditure on such vessels, which can lead to substantial savings given the large amount of resource hours spent by the USCG on Foreign flag exams and boardings. Secondly, since better information allows a narrower focus, USCG resources can be deployed more efficiently.

At Level I, estimates from the Poisson model for Personnel casualties contained in Tables E.18-E.20, and for Pollution casualties in Table E.21. Table E.18 shows that hours spent by active duty personnel (REG_HR) and hours spent by reserve personnel (RES_HR) aboard Freight ships are effective in reducing Deaths and Missing, but these hours are not effective in controlling injuries. For Passenger vessels, Table E.19 shows that Regular hours are effective in controlling injuries. For Tank ships, Table E.20 shows that Regular hours do seem to reduce injuries. Results from Table E.21 indicate that Regular hours are clearly effective in reducing Pollution casualties in vessels of all services, particularly Freight and Tank ships. Various other specifications were estimated, and if estimates on resource hours are compared across the range of specifications, we arrive at the conclusion that these estimates are not robust to changes in model specification. Certainly the Foreign flag estimates are much more sensitive than the corresponding U.S. flag results and do not allow strong and unambiguous inferences.

At Level II, the results for Personnel casualties are again sensitive to specification changes. The

duration analysis of Pollution casualties in Table E.22 leads us to the conclusion that there is some evidence, although weak, that Regular hours devoted to Annual Examination of Tank ships is effective in prolonging time to casualty. But the same results based on specifications where the resource hours are scaled by gross tonnage of the vessel, show that Annual Tank ship Examinations are ineffective (Table E.24) in prolonging the duration to a pollution casualty, while no clear inferences may be drawn about Annual Freight ship Examination (Table E.23).

E.5 Risk-Based Ranking results

From an analysis of Freight, Passenger, and Tanker vessel casualty and inspection data logged in the MSMS MINMOD database, dominant contributors to maritime risk were identified. Using MSMS casualty data between 1991 and 1993, the risk-based rankings analysis shows that MSMS MINMOD data do attribute most risks associated with Freight, Passenger, and Tanker vessel operations to casualty causes that fall under the purview of the USCG's Level III intervention strategies. The analysis indicates that most risk is attributed to causes that are linked to the Drills/Human Factors, Steering/Navigation, and Cargo/Pollution Control Level III intervention strategies, and to a much lesser degree, the Power Plant and Fire Suppression and Prevention strategies. The "importance" of risk that could not be attributed to any of the Level III activities tended to be less than 10% of the risk associated with the most dominant Level III strategies. The results for the highest level of data aggregation (USCG wide) are summarized in Tables E.26 through E.31. The general trend for U.S. Freight and Tanker vessels is the following: the most dominant risk contributor is Drills/Human Factors, followed by Steering/Navigation (which tends to be only half as important), and then Cargo/Pollution Control (approximately a third as important). For U.S. Passenger vessels results are similar except that the rankings of Drills/Human Factors and Steering/Navigation are reversed. For Foreign flag Freight and Tanker vessels the dominant risk contributor is Cargo/Pollution Control, followed by Steering/Navigation (which is almost equal in importance), and then Drills/Human Factors (which tends to be approximately only 15% as important). For Foreign flag Passenger vessels the results have Drills/Human Factors as the most dominant contributor followed by Steering/Navigation (approximately 15% as important), and no other contributors were shown to be more than 5% as important as Drills/Human Factors. Similar results can be inferred for the District level analysis.

E.6 Risk-Based Ranking and Econometric Modelling as Aids to Decision-Making

E.6.1 Methodology

The risk-based ranking methodology nicely complements econometric modelling when they are used as decision tools. The econometric estimates provide an answer to the following question: "If we increase USCG resource hours by $x\%$, how much will that buy in reduced personnel and pollution casualties?" By itself, and without making further assumptions, however, the econometric estimates will not inform USCG policy-makers how to divide a fixed pie of resources among various activities efficiently. This is especially true if, as in the case of U.S. flag deep-draft vessels, many activities are shown to be effective in reducing personnel and

pollution casualties. In order to target those activities that will give the largest returns to an increase in resource hours, decision-makers can look to risk-based ranking measures of importance to indicate areas that are large contributors to risk.

E.6.2 Implementing Results

Consider the econometric results pertaining to U.S. flag Level III activities in Tables E.11-E.17. The results from nearly all these tables attest to the fact that an increase in resource hours will lead to substantial decrease in casualties. However, in order to obtain reductions in deaths, injuries and pollution casualties, many thousand hours of resources must be devoted to these activities, and given a constraint on the number of resource hours available to the USCG, decision-makers are faced with the difficult question of how to apportion hours efficiently among activities. The importance measures from the risk-based rankings provide a natural answer. The largest increase in hours should be devoted to those activities that cover factors contributing to the greatest risk of casualties. For example, from Tables E.28 and E.30, increases in resource hours are most effective if devoted to Drills/Human Factors and Steering/Navigation on Freight ships, to Steering/Navigation and Drills /Human Factors for Passenger ships, and to Drills/Human Factors, Steering/Navigation, and Cargo Handling/Pollution Control for Tank ships. We emphasize that the risk-based ranking importance measures inform only about *contribution* of factors to risk, and we should not make strong inferences about risk *reduction* or risk *increase*. For example, just because activities other than those listed above have importance measures close to zero does not mean that removing resources from these activities will do no harm. These activities may have low importance values precisely because USCG inspections are effective in eliminating the contribution to the risk of casualties by factors covered by these activities. We need to look to the econometric estimates to provide answers about risk reduction. While so doing, the following caveats need to be observed. Firstly, the econometric estimates should not be extrapolated beyond the "experience" of the sample. Hence if the sample does not contain any observation (vessel) with zero resource hours devoted to it, we cannot ask of the econometric results to provide an answer to the question of what would happen to personnel and pollution casualties if USCG inspections and boardings came to a complete halt. Econometric estimates are most reliable for counterfactual experiments that consider small variations of resource hours around their sample means. Secondly, econometric results are not substitutes for personal judgement and expert opinions possessed by USCG personnel with substantial field experience. Rather, they are meant to complement such judgements. Where the econometric and risk-based ranking measures corroborate experience and personal judgement, the foundation for decision-making is that much stronger. Where the data-based measures conflict with personal judgement, either personal judgements must be revised, or new data must be brought to bear on the problem, or both. These recommendations are deep-rooted in the decision-theoretic literature.

E.7 The Prototype Decision Support System

A prototype DSS was developed to aid USCG program management in using the econometric models that generated measures of effectiveness for Marine Inspection and Boarding Program.

An easy to use, flexible spreadsheet format was employed for the human-machine interface. Representative models were programmed in Excel, the spreadsheet software selected for the prototype DSS, and various displays constructed. The interface with displays was assessed by USCG program management. Rapid prototyping was used as the development process.

Extensions to the prototype were suggested to incorporate measures of effectiveness into the resource allocation decision making by USCG program management. As part of the rapid prototyping process, various displays were created, implemented in Excel and presented to the USCG for review. The focus of the effort was on models for determining effectiveness as is described in a tutorial companion volume entitled, "Decision Support for Utilizing Measures of Effectiveness." In this DSS tutorial models from the econometric MOE analysis are presented. An example of the input from Model 5 of Table E.4 is displayed in Figure E.1.

Figure E.1 Model 5 From Table E.4

E.8 Recommendations for Further Analysis

1. Our recommendations for further analysis of the effectiveness of USCG activities on Foreign flag vessels has to do with the quality and completeness of the data. As it stands, the data provides information on only "half" the experiment. There is neither data on the monitoring effort on Foreign flag vessels that occurs outside U.S. waters, nor is there data on the occurrence of casualties outside U.S. waters. We are thus inferring the effectiveness of USCG activities based on a truncated information set, and clearly the inferences will be much weaker than those based on the complete information set. A fruitful line of enquiry concerns the possibility of merging the MSMS database with Lloyds' databases.

2. We strongly recommend undertaking a study that analyzes the incentive problems innate to the examination of Foreign flag vessels and designs an incentive mechanism that somewhat relieves the USCG of the burden of extracting *all* (hidden) information about the state of the vessel by ensuring that vessel operators "voluntarily" provide some information. This would enable economically better and more efficient decision-making about the Boarding Program, especially since a large proportion of USCG resources are devoted to it.
3. The mapping from inspection types in table CRST of the MSMS database into Level III activities should be a more sophisticated *fractional* mapping which gives information about the fraction of hours from a CRST inspection type that goes into each Level III activity. It may be possible to amend the CRST inspection types so that such a fractional mapping becomes more sensible. Then the Level III analysis of Foreign flag vessel examinations also becomes possible.
4. The process of developing rankings of inspection/boarding strategies important to safety depends significantly on the quality of data that identifies casual information and links it back to intervention strategies. The level of detailed cause data in MSMS MINMOD is somewhat limited, and represents a significant restructuring of casualty cause data in the transition from the old CASMAIN casualty database (more comprehensive in this regard) to the new MINMOD casualty database (less comprehensive). Our recommendation in this regard is therefore that casualty cause data should be redefined in order to be informative about Level III activities.
5. The prototype DSS should be fully implemented by incorporating additional models into the spreadsheet format in Excel. As described in the companion volume, three models were implemented for demonstration and assessment purposes. USCG staff should prioritize the model described in this report and implement as time and resources permit.
6. A "model management" interface should be developed. This interface would guide the user to the model most appropriate to the management task being addressed by USCG program staff.

Table E.1 Description of Variables

DEATHS	Number of deaths from a casualty. From CIRT.
MISSING	Number of missing from a casualty. From CIRT.
D&M	Number of deaths and missing from a casualty. From CIRT.
INJURED	Number of injuries from a casualty. From CIRT.
POLLOCCS	Number of pollution casualties. From CIRT.
DURCAS	Duration to casualty from last inspection. From CIRT, CRST.
DURNOCAS	Duration measure if no casualty. From CIRT, CRST.
REG_GT	Gross Tonnage of vessel. From VIDT.
AGE	Age of Vessel=1993-Year vessel built. From VIDT.
HULL_HR	Inspection hours on hull activities. '000 Hours. From CRST.
MACH_HR	Inspection hours on machinery activities. '000 Hours. From CRST.
ADMIN_HR	Administrative hours. '000 Hours. From CRST (MI), BRST (PS).
REG_HR	Examination hours by active duty personnel. '000 Hours. From BRST.
RES_HR	Examination hours by reserve personnel. '000 Hours. From BRST.
DF	Dummy variable. 1 if vessel is Freight ship.
DP	Dummy variable. 1 if vessel is Passenger Ship.
DT	Dummy variable. 1 if vessel is Tankship.
hour_F	Hours (HULL, MACH, ADMIN, REG, RES) $\times$ DF
hour_P	Hours (HULL, MACH, ADMIN, REG, RES) $\times$ DP
hour_T	Hours (HULL, MACH, ADMIN, REG, RES) $\times$ DT

Note:

1. DEATHS, MISSING, INJURED, POLLOCCS are sum of casualties between 1991-1993.
2. HULL_HR, MACH_HR, ADMIN_HR, REG_HR, RES_HR are sum of resource hours between 1989-1993.
3. In *all* tables, (1) *t*-values in parentheses, (2) ** indicates statistical significance at a 5% level, and * at a 10% level, (3) *N*=Number of observations, *k*=number of rhs variables, *LLR*=Likelihood Ratio statistic, which is distributed as Chi-square with *k* degrees of freedom.
4. In Tables E.11-E.17 containing results for Level III activities, the variables names are modified as follows: "D3x indicates Activity IIIx, "hhr", "mhr", "ahr", respectively, represent Hull, Machinery, and Administrative hours. "_P", "_F", "_T" indicate disaggregation by service. So, "H3x_P" represents Hull hours on Activity IIIx on Passenger vessels.

Table E.2 MOEs from a Poisson Model of Personnel Casualties: MI Cases, U.S. Flag Hours Scaled by Gross Tonnage.

Cross Section of 951 Deep Draft Vessels
Dependent variable = Number of Personnel Deaths and Missing

rhs variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	-4.573 (-5.90)**	-4.608 (-5.93)**	-4.566 (-5.89)**	-4.538 (-5.11)**	-4.042 (-3.70)**	-4.383 (-4.50)**
Hull_hr	-1.167 (-1.59)					
Mach_hr		-1.444 (1.57)				
Admin_hr			-1.033 (-1.58)			
Hull_P				-0.831 (-1.04)		
Mach_P					-1.326 (-1.11)	
Admin_P						-0.886 (-1.09)
Hull_F				-2.313 (-0.98)		
Mach_F					-1.462 (-1.01)	
Admin_F						-1.242 (-0.99)
Hull_T				-1.880 (-0.31)		
Mach_T					-17.655 (-0.61)	
Admin_T						-3.643 (-0.37)
Age	-0.007 (-0.52)	-0.008 (-0.58)	-0.008 (-0.56)	-0.006 (-0.44)	-0.008 (-0.54)	-0.008 (-0.52)
DP	2.148 (2.09)**	2.063 (2.05)**	2.134 (2.10)**	1.828 (1.48)	1.424 (1.05)	1.807 (1.40)
DF	1.732 (2.33)**	1.739 (2.34)**	1.723 (2.32)**	1.774 (1.99)**	1.164 (1.08)	1.549 (1.60)
N	951	951	951	951	951	951
k	4	4	4	6	6	6
LLR	17.66	15.77	17.60	18.19	16.34	17.78
Obs. y>0	14	14	14	14	14	14

**Table E.3 MOEs from a Poisson Model of Personnel Casualties: MI Cases, U.S. Flag Hours
Scaled by Gross Tonnage**

Cross Section of 951 Deep Draft Vessels
Dependent variable = Number of Personnel Injuries

rhs variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	-0.106 (-0.98)	-0.092 (-0.85)	-0.104 (-0.96)	0.127 (1.02)	0.050 (0.41)	0.058 (0.49)
Hull_hr	-0.212 (-5.03)**					
Mach_hr		-0.528 (-5.44)**				
Admin_hr			-0.169 (-4.80)**			
Hull_P				0.295 (5.13)**		
Mach_P					0.041 (0.35)	
Admin_P						0.161 (4.03)**
Hull_F				-0.534 (-4.36)**		
Mach_F					-1.076 (-4.26)**	
Admin_F						-0.612 (-4.34)**
Hull_T				-2.998 (-2.76)**		
Mach_T					-3.506 (-2.49)**	
Admin_T						-2.063 (-2.65)**
Age	-0.022 (-6.38)**	-0.023 (-6.58)**	-0.023 (-6.52)**	-0.022 (-6.12)**	-0.022 (-6.12)**	-0.021 (-5.91)**
DP	0.259 (1.62)	0.454 (2.71)**	0.260 (1.63)	-0.904 (-4.03)**	-0.275 (-1.27)	-0.667 (-3.19)**
DF	0.292 (2.94)**	0.305 (3.06)**	0.287 (2.89)**	0.115 (0.94)	0.193 (1.62)	0.178 (1.53)
N	951	951	951	951	951	951
k	4	4	4	6	6	6
LLR	128.31	137.77	123.60	208.78	173.59	203.38
Obs. y>0	247	247	247	247	247	247

**Table E.4 MOEs from a Poisson Model of Pollution Casualties: MI Cases, U.S. Flag Hours
Scaled by Gross Tonnage.**

Cross Section of 804 Deep Draft Vessels
Dependent variable (y) = Number of Pollution Incidents

rhs variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	-0.837 (-5.35)**	-0.838 (-5.35)**	-0.830 (-5.30)**	-0.816 (-5.22)**	-0.826 (-5.27)**	-0.807 (-5.16)**
Hull_hr	-0.138 (-2.82)**					
Mach_hr		-0.258 (-2.51)**				
Admin_hr			-0.132 (-2.81)**			
Hull_F				-0.075 (-1.30)		
Mach_F					-0.178 (-1.34)	
Admin_F						-0.067 (-1.26)
Hull_T				-0.223 (-2.37)**		
Mach_T					-0.350 (-2.03)**	
Admin_T						-0.230 (-2.28)**
Age	-0.007 (-1.37)	-0.008 (-1.49)	-0.008 (-1.42)	-0.007 (-1.30)	-0.008 (-1.46)	-0.007 (-1.33)
DF	-0.551 (-3.85)**	-0.544 (-3.80)**	-0.553 (-3.86)**	-0.611 (-4.09)**	-0.579 (-3.87)**	-0.618 (-4.15)**
N	804	804	804	804	804	804
k	3	3	3	4	4	4
LLR	31.98	29.21	32.86	34.05	29.86	35.38
Obs. with y>0	144	144	144	144	144	144

**Table E.5 MOEs from an Exponential Duration Model of Personnel Casualties: MI Cases, U.S.
Flag Hours Scaled by Gross Tonnage.**

Cross Section of 1,278 II.A.1 Activities (COI)

Dependent variable (y) = Duration to Personnel Casualty (Deaths, Missing, Injured)

rhs variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	6.556 (237.11)**	6.555 (237.08)**	6.555 (236.92)**	6.555 (236.19)**	6.554 (236.20)**	6.554 (235.84)**
Hull_hr	0.025 (1.58)					
Mach_hr		0.038 (2.04)**				
Admin_hr			0.033 (2.06)**			
Hull_P				0.089 (1.04)		
Mach_P					0.093 (0.89)	
Admin_P						0.068 (0.67)
Hull_F				0.036 (1.51)		
Mach_F					0.065 (1.89)*	
Admin_F						0.047 (2.07)**
Hull_T				0.018 (0.96)		
Mach_T					0.027 (1.52)	
Admin_T						0.024 (1.29)
Age	0.005 (5.81)**	0.005 (5.81)**	0.005 (5.78)**	0.005 (5.51)**	0.005 (5.63)**	0.005 (5.57)**
N	1,278	1,278	1,278	1,278	1,278	1,278
k	2	2	2	4	4	4
LLR	8.42	8.50	8.57	8.54	8.63	8.63
Obs. y>0	256	256	256	256	256	256

**Table E.6 MOEs from an Exponential Duration Model of Pollution Casualties: MI Cases, U.S.
Flag Hours Scaled by Gross Tonnage.**

Cross Section of 1,278 II.A.1 Activities (COI)
Dependent variable (y) = Duration to Pollution Casualty

rhs variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	6.719 (319.59)**	6.719 (319.42)**	6.719 (319.47)**	6.719 (318.50)**	6.719 (318.27)**	6.719 (318.35)**
Hull_hr	0.002 (0.17)					
Mach_hr		0.011 (0.76)				
Admin_hr			0.005 (0.36)			
Hull_P				0.028 (0.36)		
Mach_P					0.055 (0.62)	
Admin_P						-0.004 (-0.05)
Hull_F				0.007 (0.35)		
Mach_F					0.028 (0.95)	
Admin_F						0.008 (0.44)
Hull_T				-0.000 (-0.02)		
Mach_T					0.004 (0.26)	
Admin_T						0.003 (0.17)
Age	0.002 (2.92)**	0.002 (2.85)**	0.002 (2.90)**	0.002 (2.73)**	0.002 (2.67)**	0.002 (2.82)**
N	1,278	1,278	1,278	1,278	1,278	1,278
k	2	2	2	4	4	4
LLR	1.23	1.26	1.24	1.25	1.32	1.24
Obs. y>0	158	158	158	158	158	158

Table E.7 MOEs from an Exponential Duration Model of Personnel Casualties (MINMOD)
Hours Scaled by Gross Tonnage. MI Cases, U.S. Flag

Cross Section of 1,021 I.I.A.2 Activities (REINSPECTION)
 Dependent variable (y) = Duration to Personnel Casualty (Deaths, Missing, Injured)

rhs variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	6.587 (222.21)**	6.589 (222.92)**	6.583 (221.68)**	6.579 (220.59)**	6.581 (220.60)**	6.576 (220.60)**
Hull_hr	0.054 (2.38)**					
Mach_hr		0.060 (1.85)*				
Admin_hr			0.076 (3.51)**			
Hull_P				0.311 (3.92)**		
Mach_P					0.323 (3.93)**	
Admin_P						0.251 (4.68)**
Hull_F				0.087 (3.62)**		
Mach_F					0.119 (3.20)**	
Admin_F						0.091 (2.76)**
Hull_T				0.032 (1.36)		
Mach_T					0.025 (0.96)	
Admin_T						0.051 (2.23)**
Age	0.003 (2.90)**	0.003 (2.88)**	0.003 (2.79)**	0.002 (2.48)**	0.002 (2.52)**	0.002 (2.51)**
N	1,021	1,021	1,021	1,021	1,021	1,021
k	2	2	2	4	4	4
LLR	3.99	3.45	5.24	6.01	5.44	6.95
Obs. y>0	230	230	230	230	230	230

Table E.8 MOEs from an Exponential Duration Model of Pollution Casualties (MINMOD)
Hours Scaled by Gross Tonnage. MI Cases, U.S. Flag

Cross Section of 1,021 I.L.A.2 Activities (REINSPECTION)
 Dependent variable (y) = Duration to Pollution Casualty

rhs variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	6.775 (286.70)**	6.775 (287.25)**	6.774 (285.88)**	6.770 (284.34)**	6.771 (285.02)**	6.769 (284.22)**
Hull_hr	0.008 (0.50)					
Mach_hr		0.003 (0.14)				
Admin_hr			0.003 (1.61)			
Hull_P				0.199 (3.11)**		
Mach_P					0.219 (3.41)**	
Admin_P						0.181 (4.18)**
Hull_F				0.023 (1.05)		
Mach_F					0.004 (0.12)	
Admin_F						0.016 (0.60)
Hull_T				-0.002 (-0.13)		
Mach_T					-0.011 (-0.56)	
Admin_T						0.017 (0.85)
Age	0.000 (0.18)	0.000 (0.25)	-0.000 (-0.00)	-0.000 (-0.17)	-0.000 (-0.12)	-0.000 (-0.28)
N	1,021	1,021	1,021	1,021	1,021	1,021
k	2	2	2	4	4	4
LLR	0.05	0.02	0.38	1.06	1.14	1.58
Obs. y>0	121	121	121	121	121	121

**Table E.9 MOEs from an Exponential Duration Model of Personnel Casualties (MINMOD)
Hours Scaled by Gross Tonnage. MI Cases, U.S. Flag**

Cross Section of 856 II.A.3 Activities (HULL)

Dependent variable (y) = Duration to Personnel Casualty (Deaths, Missing, Injured)

rhs variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	6.539 (199.63)**	6.537 (198.81)**	6.540 (199.65)**	6.540 (197.92)**	6.532 (198.16)**	6.543 (198.71)**
Hull_hr	0.049 (3.12)**					
Mach_hr		0.048 (1.05)				
Admin_hr			0.050 (2.75)**			
Hull_P				0.236 (2.26)**		
Mach_P					0.141 (0.47)	
Admin_P						0.318 (1.92)*
Hull_F				0.062 (3.17)**		
Mach_F					0.132 (3.11)**	
Admin_F						0.058 (2.09)**
Hull_T				0.038 (1.82)*		
Mach_T					-0.063 (-2.98)**	
Admin_T						0.046 (2.17)**
Age	0.004 (4.17)**	0.005 (4.77)**	0.005 (4.25)**	0.004 (3.67)**	0.005 (4.85)**	0.004 (3.63)**
N	856	856	856	856	856	856
k	2	2	2	4	4	4
LLR	6.50	5.34	6.07	7.04	6.37	6.50
Obs. y>0	188	188	188	188	188	188

**Table E.10 MOEs from an Exponential Duration Model of Pollution Casualties (MINMOD)
Hours Scaled by Gross Tonnage. MI Cases, U.S. Flag**

Cross Section of 856 II.A.3 Activities (HULL)
Dependent variable (y) = Duration to Pollution Casualty

rhs variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	6.727 (256.51)**	6.726 (255.63)**	6.727 (256.67)**	6.728 (255.92)**	6.721 (256.31)**	6.730 (256.61)**
Hull_hr	0.022 (1.43)					
Mach_hr		-0.008 (-0.21)				
Admin_hr			0.021 (1.29)			
Hull_P				0.183 (1.86)*		
Mach_P					-0.039 (-0.19)	
Admin_P						0.217 (1.48)**
Hull_F				0.032 (1.84)*		
Mach_F					0.080 (2.13)**	
Admin_F						0.020 (0.86)
Hull_T				0.014 (0.61)		
Mach_T					-0.011 (-2.70)**	
Admin_T						0.023 (1.15)
Age	0.001 (0.96)	0.001 (1.32)	0.001 (1.01)	0.001 (0.57)	0.001 (1.47)	0.001 (0.57)
N	856	856	856	856	856	856
k	2	2	2	4	4	4
LLR	0.54	0.27	0.44	0.93	1.29	0.67
Obs. y>0	119	119	119	119	119	119

Table E.11 MOEs from a Poisson Model of Pollution Casualties (MINMOD) Hours Scaled by Gross Tonnage. MI Cases, U.S. Flag Hours Devoted to Activity III.1

Dependent variable (y) = Number of Pollution Incidents

rhs variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	-0.811 (-5.30)**	-0.804 (-5.25)**	-0.797 (-5.20)**	-0.787 (-5.15)**	-0.799 (-5.21)**	-0.783 (-5.11)**
D31hr	-1.147 (-2.66)**					
D31mhr		-3.377 (-2.85)**				
D31ahr			-1.738 (-2.95)**			
H31_P				-1.600 (-0.63)		
H31_F				-0.507 (-1.06)		
H31_T				-2.070 (-2.30)**		
M31_P					-15.106 (-2.04)**	
M31_F					-2.464 (-1.62)	
M31_T					-3.223 (-1.99)**	
A31_P						-9.781 (-1.88)*
A31_F						-0.908 (-1.30)
A31_T						-2.277 (-2.24)**
Age	-0.009 (-1.71)*	-0.009 (-1.71)*	-0.009 (-1.63)	-0.009 (-1.64)	-0.008 (-1.77)*	-0.009 (-1.63)
DP	-1.507 (-4.26)**	-1.356 (-3.76)**	-1.463 (-4.11)*	-1.482 (-3.06)**	-0.660 (-1.40)	-0.780 (-1.63)
DF	-0.557 (-3.89)**	-0.548 (-3.83)**	-0.569 (-3.97)**	-0.621 (-4.19)**	-0.562 (-3.78)**	-0.613 (-4.14)**
N	951	951	951	951	951	951
k	4	4	4	6	6	6
LLR	57.75	60.96	69.34	60.62	64.90	68.47
Obs. y>0	151	151	151	151	151	151

Table E.12 MOEs from a Poisson Model of Personnel Casualties (MINMOD) Hours Scaled by Gross Tonnage. MI Cases, U.S. Flag Hours Devoted to Activity III.2-7,9
Dependent variable (y) = Number of Personnel Deaths and Missing

rhs variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	-4.608 (-5.94)**	-4.614 (-5.94)**	-4.595 (-5.92)**	-4.404 (-4.50)**	-4.163 (-3.86)**	-4.322 (-4.29)**
D32hr	-9.024 (-1.44)					
D32mhr		-13.994 (-1.54)				
D32ahr			-10.019 (-1.48)			
H32_P				-6.920 (-0.94)		
H32_F				-12.846 (-0.88)		
H32_T				-44.063 (-0.36)		
M32_P					-12.268 (-1.08)	
M32_F					-15.320 (-0.98)	
M32_T					-157.396 (-0.52)	
A32_P						-8.496 (-1.03)
A32_F						-11.574 (-0.93)
A32_T						-64.405 (-0.40)
Age	-0.008 (-0.53)	-0.009 (-0.58)	-0.008 (-0.55)	-0.007 (-0.50)	-0.008 (-0.55)	-0.008 (-0.52)
DP	1.894 (1.90)*	1.982 (2.00)**	1.933 (1.94)*	1.526 (1.22)	1.436 (1.09)	1.549 (1.22)
DF	1.708 (2.30)**	1.724 (2.32)**	1.701 (2.29)**	1.528 (1.57)	1.270 (1.19)	1.430 (1.44)
N	951	951	951	951	951	951
k	4	4	4	6	6	6
LLR	15.89	15.45	16.25	16.21	15.90	16.54
Obs. y>0	14	14	14	14	14	14

Table E.13 MOEs from a Poisson Model of Personnel Casualties (MINMOD) Hours Scaled by Gross Tonnage. MI Cases, U.S. Flag

Hours Devoted to Activity III.2-7,9, Dependent variable (y) = Number of Personnel Injured

rhs variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	-0.102 (-0.94)	-0.099 (-0.92)	-0.100 (-0.93)	0.121 (0.97)	0.050 (0.42)	0.066 (0.56)
D32hhr	-2.253 (-4.96)**					
D32mhr		-4.631 (-5.09)**				
D32ahr			-2.121 (-4.79)**			
H32_P				2.218 (3.91)**		
H32_F				-5.514 (-4.16)**		
H32_T				-35.054 (-2.65)**		
M32_P					0.795 (0.77)	
M32_F					-10.241 (-4.10)**	
M32_T					-38.855 (-2.45)**	
A32_P						2.167 (4.39)**
A32_F						-7.426 (-4.15)**
A32_T						-24.362 (-2.54)**
Age	-0.023 (-6.41)**	-0.023 (-6.59)**	-0.023 (-6.45)**	-0.022 (-6.16)**	-0.022 (-6.18)**	-0.022 (-6.21)**
DP	0.250 (1.57)	0.391 (2.36)**	0.235 (1.47)	-0.701 (-3.30)**	-0.314 (-1.50)	-0.644 (-3.18)**
DF	0.280 (2.82)**	0.294 (2.96)**	0.274 (2.75)**	0.102 (0.84)	0.177 (1.51)	0.178 (1.56)
N	951	951	951	951	951	951
k	4	4	4	6	6	6
LLR	128.36	130.00	125.12	194.54	169.67	201.46
Obs. y>0	247	247	247	247	247	247

Table E.14 MOEs from a Poisson Model of Pollution Casualties (MINMOD) Hours Scaled by Gross Tonnage. MI Cases, U.S. Flag Hours Devoted to Activity III.2-7,9

Dependent variable (y) = Number of Pollution Incidents

rhs variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	-0.805 (-5.26)**	-0.805 (-5.26)**	-0.798 (-5.21)**	-0.790 (-5.16)**	-0.800 (-5.22)**	-0.783 (-5.11)**
D32hr	-1.481 (-2.88)**					
D32mhr		-3.343 (-2.81)**				
D32ahr			-1.759 (-2.98)**			
H32_P				-5.922 (-1.49)		
H32_F				-0.716 (-1.16)		
H32_T				-2.135 (-2.35)**		
M32_P					-15.046 (-2.05)**	
M32_F					-2.371 (-1.55)	
M32_T					-3.224 (-1.99)**	
A32_P						-9.780 (-1.88)*
A32_F						-0.903 (-2.29)**
A32_T						-2.330 (-2.29)**
Age	-0.009 (-1.66)*	-0.009 (-1.70)*	-0.009 (-1.63)	-0.009 (-1.62)	-0.009 (-0.76)	-0.009 (-1.62)
DP	-1.482 (-4.18)**	-1.363 (-3.87)**	-1.460 (-4.11)**	-1.038 (-2.13)**	-0.666 (-1.42)	-0.780 (-1.63)
DF	-0.562 (-3.92)**	-0.550 (-3.84)**	-0.568 (-3.97)**	-0.614 (-4.14)**	-0.566 (-3.80)**	-0.614 (-4.14)**
N	951	951	951	951	951	951
k	4	4	4	6	6	6
LLR	59.68	60.48	63.08	63.18	64.49	68.30
Obs. y>0	151	151	151	151	151	151

Table E.15 MOEs from a Poisson Model of Personnel Casualties (MINMOD) Hours Scaled by Gross Tonnage. MI Cases, U.S. Flag Hours Devoted to Activity III.8
 Dependent variable (y) = Number of Personnel Deaths and Missing

rhs variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	-4.593 (-5.93)**	-4.620 (-5.95)**	-4.598 (-5.93)**	-4.411 (-4.43)**	-4.036 (-3.79)**	-4.310 (-4.23)**
D38hr	-7.575 (-1.50)					
D38mhr		-11.445 (-1.50)				
D38ahr			-7.206 (-1.49)			
H38_P				-4.763 (-0.89)		
H38_F				-18.187 (-0.98)		
H38_T				-32.802 (-0.33)		
M38_P					-9.921 (-1.02)	
M38_F					-12.337 (-0.97)	
M38_T					-184.212 (-0.63)	
A38_P						-4.823 (-0.87)
A38_F						-12.032 (-0.93)
A38_T						-51.593 (-0.41)
Age	-0.008 (-0.52)	-0.009 (-0.58)	-0.008 (-0.52)	-0.007 (-0.46)	-0.008 (-0.55)	-0.007 (-0.48)
DP	1.934 (1.94)*	1.939 (1.95)*	1.891 (1.90)*	1.459 (1.15)	1.253 (0.95)	1.357 (1.05)
DF	1.698 (2.28)**	1.722 (2.32)**	1.691 (2.27)**	1.603 (1.61)	1.134 (1.08)	1.434 (1.42)
N	951	951	951	951	951	951
k	4	4	4	6	6	6
LLR	16.17	14.89	15.74	17.05	15.59	16.36
Obs. y>0	14	14	14	14	14	14

Table E.16 MOEs from a Poisson Model of Personnel Casualties (MINMOD) Hours Scaled by Gross Tonnage. MI Cases, U.S. Flag Hours Devoted to Activity III.8

Dependent variable (y) = Number of Personnel Injured

rhs variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	-0.131 (-1.21)	-0.091 (-0.84)	-0.129 (-1.19)	0.191 (1.53)	0.052 (0.43)	0.086 (0.74)
D38hhr	-0.559 (-2.77)**					
D38mhr		-4.750 (-5.25)**				
D38ahr			-0.605 (-2.78)**			
H38_P				3.865 (11.16)**		
H38_F				-2.360 (-3.80)**		
H38_T				-23.765 (-2.42)**		
M38_P					-0.006 (-0.01)	
M38_F					-9.504 (-4.05)**	
M38_T					-33.101 (-2.56)**	
A38_P						1.909 (9.22)**
A38_F						-3.931 (-4.18)**
A38_T						-16.595 (-2.48)**
Age	-0.024 (-6.87)**	-0.023 (-6.62)**	-0.024 (-6.81)**	-0.027 (-7.06)**	-0.022 (-6.21)**	-0.024 (-6.44)**
DP	0.128 (0.83)	0.433 (2.60)**	0.129 (0.83)	-1.479 (-6.18)**	-0.218 (-1.08)	-0.800 (-4.14)**
DF	0.288 (2.90)**	0.299 (3.00)**	0.279 (2.80)**	0.079 (0.65)	0.181 (1.55)	0.158 (1.41)
N	951	951	951	951	951	951
k	4	4	4	6	6	6
LLR	91.34	136.03	91.25	254.90	169.95	220.30
Obs. y>0	247	247	247	247	247	247

Table E.17 MOEs from a Poisson Model of Pollution Casualties (MINMOD) Hours Scaled by Gross Tonnage. MI Cases, U.S. Flag Hours Devoted to Activity III.8
 Dependent variable (y) = Number of Pollution Incidents

rhs variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	-0.810 (-5.29)**	-0.810 (-5.29)**	-0.806 (-5.27)**	-0.783 (-5.14)**	-0.791 (-5.17)**	-0.777 (-5.09)**
D38hhr	-0.894 (-2.46)**					
D38mhr		-2.098 (-2.43)**				
D38ahr			-1.604 (-2.63)**			
H38_P				-5.152 (-1.60)		
H38_F				-0.204 (-0.55)		
H38_T				-1.766 (-2.37)**		
M38_P					-11.878 (-1.95)*	
M38_F					-0.827 (-0.83)	
M38_T					-3.017 (-1.96)**	
A38_P						-7.535 (-1.88)*
A38_F						-0.207 (-0.44)
A38_T						-1.834 (-2.31)**
Age	-0.009 (-1.79)*	-0.010 (-1.85)*	-0.009 (-1.72)*	-0.009 (-1.66)*	-0.010 (-1.85)*	-0.009 (-1.68)*
DP	-1.495 (-4.23)**	-1.424 (-3.99)**	-1.482 (-4.19)**	-0.968 (-1.98)**	-0.734 (-1.53)	-0.766 (-1.58)
DF	-0.556 (-3.88)**	-0.547 (-3.82)**	-0.566 (-3.95)**	-0.642 (-4.31)**	-0.600 (-4.02)**	-0.647 (-4.33)**
N	951	951	951	951	951	951
k	4	4	4	6	6	6
LLR	54.29	54.77	56.43	61.11	60.05	64.28
Obs. y>0	151	151	151	151	151	151

**Table E.18 MOEs from a Poisson Model of Personnel Casualties
(MINMOD) PS Cases, Foreign Flag**

Cross Section of 8336 Freight Vessels
Dependent variable (y) = Number of personnel affected

lhs variable (y)		
rhs variables	Deaths and Missing	Injuries
Constant	-3.033 (-1.47)	-3.883 (-2.60)**
Reg_gt	-0.273 (-1.38)	-0.243 (-1.69)*
Reg_hr	-1.309 (-1.75)*	-0.005 (-0.08)
Res_hr	-1.459 (-1.55)	0.113 (0.67)
Admin_hr	2.603 (3.00)**	0.659 (3.10)**
Age	-0.021 (-0.65)	0.0406 (1.99)**
<i>N</i>	8336	8336
<i>k</i>	5	5
<i>LLR</i>	17.109	13.978
<i>Mad. R²</i>	0.044	0.024
Obs. with y>0	18	32

Note:

(1) *t*-values in parentheses.

(2) ** indicates statistical significance at the 5% level, and * at the 10% level.

(3) *N*=Number of observations, *k*=number of rhs variables, *LLR*=Likelihood Ratio Chi-square, *Mad. R²*=Madalla's pseudo R-square.

**Table E.19 MOEs from a Poisson Model of Personnel Casualties
(MINMOD) PS Cases, Foreign Flag**

Cross Section of 200 Passenger Vessels
Dependent variable (y) = Number of personnel affected

lhs variable (y)	rhs variables	
	Deaths and Missing	Injuries
Constant	No values calculated for deaths and missing due to non-convergence	-39.351 (-8.62)**
Reg_gt		3.437 (8.34)**
Reg_hr		-8.425 (-4.30)**
Res_hr		9.269 (4.95)**
Admin_hr		8.631 (4.30)**
Age		0.069 (3.48)**
<i>N</i>	200	200
<i>k</i>	5	5
<i>LLR</i>		179.644
<i>Mad. R²</i>		0.732
Obs. with y>0	0	5

Note:

(1) *t*-values in parentheses.

(2) ** indicates statistical significance at the 5% level, and * at the 10% level.

(3) *N*=Number of observations, *k*=number of rhs variables, *LLR*=Likelihood Ratio Chi-square, *Mad. R²*=Madalla's pseudo R-square.

**Table E.20 MOEs from a Poisson Model of Personnel Casualties
(MINMOD)**

PS Cases, Foreign Flag

Cross Section of 2368 Tank Vessels
Dependent variable (y) = Number of personnel affected

lhs variable (y) rhs variables	Deaths and Missing	Injuries
Constant	-14.238 (-1.49)	1.043 (0.44)
Reg_gt	0.570 (0.65)	-0.593 (-2.68)**
Reg_hr	1.559 (1.26)	-0.710 (-1.56)
Res_hr	1.925 (0.88)	0.061 (0.08)
Admin_hr	-2.440 (-1.25)	1.748 (2.88)**
Age	0.067 (0.91)	-0.011 (-0.34)
<i>N</i>	2368	2368
<i>k</i>	5	5
<i>LLR</i>	3.954	23.984
<i>Mad. R²</i>	0.086	0.077
Obs. with y>0	3	18

Note:

- (1) *t*-values in parentheses.
- (2) ** indicates statistical significance at the 5% level, and * at the 10% level.
- (3) *N*=Number of observations, *k*=number of rhs variables, *LLR*=Likelihood Ratio Chi-square, *Mad. R²*=Madalla's pseudo R-square.

**Table E.21 MOEs from a Poisson Model of Pollution Casualties
(MINMOD) PS Cases, Foreign Flag**

Cross Section of *N* Deep Draft Vessels
Dependent variable (*y*) = Number of Pollution Occurrences

rhs variables	Freight	Passenger	Tank
Constant	-1.609 (-2.84)**	-9.514 (-2.95)**	-0.327 (-0.35)
Reg_gt	-0.281 (-5.20)**	0.758 (2.31)**	-0.306 (-3.50)**
Reg_hr	-0.557 (-2.88)**	-0.780 (1.09)	-0.406 (-2.66)**
Res_hr	0.122 (1.16)	1.260 (1.54)	0.419 (1.57)
Admin_hr	1.502 (6.67)**	0.934 (1.14)	1.294 (5.84)**
Age	0.034 (4.17) **	0.014 (1.19)	0.021 (1.99)**
<i>N</i>	8339	200	2368
<i>k</i>	5	5	5
<i>LLR</i>	179.00	17.429	146.628
<i>Mad. R²</i>	0.067	0.086	0.105
Obs. with <i>y</i> >0	285	25	172

Note:

(1) *t*-values in parentheses.

(2) ** indicates statistical significance at the 5% level, and * at the 10% level.

(3) *N*=Number of observations, *k*=number of rhs variables, *LLR*=Likelihood Ratio Chi-square, *Mad. R²*=Madalla's pseudo R-square.

**Table E.22 MOEs from an Exponential Duration Model of Pollution Casualties
(MINMOD) PS Cases, Foreign Flag, 1991-1993**

Cross Section of *N* I.I.B Activities (Annual Foreign Vessel Examination)
Dependent variable (*y*) = Duration to Pollution Casualty

rhs variables	Freight	Passenger	Tank
Constant	6.883 (168.25)**	7.487 (26.22)**	6.645 (71.02)**
Reg_gt	0.007 (1.78)*	-0.056 (-1.94)*	0.016 (1.78)*
Reg_hr	-0.010 (-0.25)	-0.157 (-0.96)	0.127 (1.26)
Res_hr	0.049 (1.10)	-0.093 (-0.19)	0.188 (1.76)*
Admin_hr	-0.954 (-22.90)**	-0.879 (-4.34)**	-1.133 (-11.05)**
Age	0.001 (3.08)**	0.001 (0.67)	.001 (1.27)
<i>N</i>	12912	233	3328
<i>k</i>	5	5	5
<i>LLR</i>	221.22	6.41	85.70
Obs. with <i>y</i> >0	462	11	318

Note:

- (1) *t*-values in parentheses.
- (2) ** indicates statistical significance at the 5% level, and * at the 10% level.
- (3) *N*=Number of observations, *k*=number of rhs variables, *LLR*=Likelihood Ratio Chi-square.

Table E.23 MOEs from an Exponential Duration Model of Pollution Casualties (MINMOD) Hours Scaled by Gross Tonnage. PS Cases, Foreign Flag

Level II.B.1: Cross Section of 12912 Annual FREIGHT Exams
Dependent variable (y) = Duration to Pollution Casualty

rhs variables	Model 1	Model 2	Model 3	Model 4
Constant	6.810 (914.84)**	6.810 (911.88)**	6.811 (910.20)**	6.810 (913.96)**
Reg_hr	0.372 (2.76)**	-0.294 (-4.15)**		
Res_hr	0.048 (0.29)		0.040 (0.48)	
Admin_hr	-0.883 (-6.04)**			-0.513 (-7.50)**
Age	0.003 (5.39)**	0.003 (5.07)**	0.002 (4.19)**	0.003 (5.56)**
<i>N</i>	12,912	12,912	12,912	12,912
<i>k</i>	4	2	2	2
<i>LLR</i>	19.44	8.62	2.20	17.23
Obs. with y>0	462	462	462	462

Note:

(1) *t*-values in parentheses.

(2) ** indicates statistical significance at the 5% level, and * at the 10% level.

(3) *N*=Number of observations, *k*=number of rhs variables, *LLR*=Likelihood Ratio Chi-square.

Table E.24 MOEs from an Exponential Duration Model of Pollution Casualties (MINMOD) Hours Scaled by Gross Tonnage. PS Cases, Foreign Flag

Level II.B.2: Cross Section of 3328 Annual TANKSHIP Exams

Dependent variable (y) = Duration to Pollution Casualty

rhs variables	Model 1	Model 2	Model 3	Model 4
Constant	6.760 (487.43)**	6.760 (488.71)**	6.762 (486.65)**	6.760 (488.16)**
Reg_hr	-0.064 (-3.44)**	-0.120 (-3.32)**		
Res_hr	0.202 (0.67)		-0.199 (-1.07)	
Admin_hr	-0.352 (-1.46)			-0.362 (-2.07)**
Age	0.002 (2.34)**	0.002 (2.15)**	0.002 (1.91)*	0.002 (2.30)**
<i>N</i>	3,328	3,328	3,328	3,328
<i>k</i>	4	2	2	2
<i>LLR</i>	2.72	1.52	0.76	2.42
Obs. with y>0	318	318	318	318

Note:

(1) *t*-values in parentheses.

(2) ** indicates statistical significance at the 5% level, and * at the 10% level.

(3) *N*=Number of observations, *k*=number of rhs variables, *LLR*=Likelihood Ratio Chi-square.

Table E.25 MOEs from an Exponential Duration Model of Pollution Casualties (MINMOD) Hours Scaled by Gross Tonnage. PS Cases, Foreign Flag

Level II.B.3: Cross Section of 233 Annual PASSENGER Exams

Dependent variable (y) = Duration to Pollution Casualty

rhs variables	Model 1	Model 2	Model 3	Model 4
Constant	6.795 (158.72)**	6.794 (168.40)**	6.80 (167.01)**	6.794 (168.69)**
Reg_hr	0.496 (0.16)	-0.101 (-0.34)		
Res_hr	-6.165 (-0.45)		-6.147 (-0.45)	
Admin_hr	-0.602 (-0.20)			-0.106 (-0.37)
Age	0.002 (0.83)	0.002 (0.78)	0.002 (0.81)	0.002 (0.79)
<i>N</i>	233	233	233	233
<i>k</i>	4	2	2	2
<i>LLR</i>	0.11	0.08	0.10	0.08
Obs. with y>0	11	11	11	11

Note:

(1) *t*-values in parentheses.

(2) ** indicates statistical significance at the 5% level, and * at the 10% level.

(3) *N*=Number of observations, *k*=number of rhs variables, *LLR*=Likelihood Ratio Chi-square.

Table E.26 Risk-Based Ranking Bin Data Summary - USCG Wide Aggregation, U.S. Flag

Service	Inspections	Casualties	Relative Frequency	Casualty Frequency	Casualty Frequency Standard Deviation	Consequences			
						Deaths	Injuries	Property Losses	Pollution Releases (gal.)
FREIGHTER	1924	985	0.5072	0.51195	0.0114	11	324	\$27,708,561	47,676
PASSENGER	4685	337	0.1735	0.07193	0.0038	2	50	\$2,863,371	1259
TANKER	1204	620	0.3193	0.51495	0.0144	4	167	\$6,554,482	8599
Total	7813	1942	1.0	-	-	17	541	\$37,126,414	57,534

Table E.27 Risk-Based Ranking Bin Data Summary - USCG Wide Aggregation, Foreign Flag

Service	Boardings	Casualties	Relative Frequency	Casualty Frequency	Casualty Frequency Standard Deviation	Consequences			
						Deaths	Injuries	Property Losses	Pollution Releases (gal.)
FREIGHTER	17,916	870	0.67	0.05	0.0016	9	23	\$23,959,892	440,208
PASSENGER	99	62	0.05	0.63	0.049	1	28	\$13,020,000	300
TANKER	2557	363	0.28	0.14	0.0069	3	15	\$2,679,945	161,471
Total	20,572	1295	1.0	-	-	13	66	\$39,659,837	601,979

Table E.28 Risk-Based Ranking - USCG Wide Aggregation, US Flag, Relative Frequency Weighting

Service	Consequence	Level III Intervention Strategies									
		Cargo/ Poll.	Steering/ Nav.	Documents/ Paperwork	Drills/ Human Factors	Auxiliary Sys.	Power Plant	Fire Prevention	Hull	Lifesaving	Other
Freight	Deaths	0.29	0.50	0.00	1.00	0.00	0.08	0.04	0.10	0.00	0.08
	Injuries	0.30	0.48	0.00	1.00	0.00	0.08	0.04	0.13	0.00	0.07
	Property	0.37	0.57	0.00	1.00	0.00	0.11	0.05	0.14	0.00	0.07
	Pollution	0.22	0.43	0.00	1.00	0.00	0.05	0.03	0.08	0.00	0.07
Passenger	Deaths	0.09	1.00	0.00	0.42	0.00	0.05	0.07	0.07	0.00	0.07
	Injuries	0.10	1.00	0.00	0.38	0.00	0.16	0.08	0.10	0.00	0.03
	Property	0.10	1.00	0.00	0.36	0.00	0.16	0.08	0.07	0.00	0.03
	Pollution	0.17	1.00	0.00	0.36	0.00	0.12	0.06	0.03	0.00	0.06
Tanker	Deaths	0.51	0.67	0.00	1.00	0.00	0.05	0.01	0.18	0.00	0.14
	Injuries	0.55	0.71	0.00	1.00	0.00	0.10	0.03	0.21	0.00	0.08
	Property	0.59	0.99	0.00	1.00	0.00	0.10	0.03	0.22	0.00	0.09
	Pollution	0.80	0.74	0.00	1.00	0.00	0.13	0.05	0.31	0.00	0.08

Table E.29 Risk-Based Ranking - USCG Wide Aggregation, Foreign Flag, Relative Frequency Weighting

Service	Consequence	Level III Intervention Strategies									
		Cargo/ Poll.	Steering/ Nav.	Documents/ Paperwork	Drills Human Factors	Auxiliary Sys.	Power Plant	Fire	Hull	Lifesaving	Other
Freight	Deaths	1.00	0.84	0.00	0.11	0.00	0.08	0.02	0.06	0.00	0.07
	Injuries	0.94	1.00	0.00	0.15	0.00	0.10	0.02	0.06	0.00	0.08
	Property	1.00	0.87	0.00	0.13	0.00	0.09	0.02	0.07	0.00	0.06
	Pollution	1.00	0.88	0.00	0.10	0.00	0.10	0.01	0.05	0.00	0.07
Passenger	Deaths	0.00	0.14	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
	Injuries	0.05	0.16	0.00	1.00	0.00	0.01	0.02	0.00	0.00	0.00
	Property	0.00	0.14	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pollution	1.00	0.29	0.00	0.46	0.00	0.14	0.29	0.00	0.00	0.00
Tanker	Deaths	1.00	0.76	0.00	0.14	0.00	0.05	0.06	0.04	0.00	0.06
	Injuries	1.00	0.92	0.00	0.18	0.00	0.04	0.11	0.08	0.00	0.08
	Property	1.00	0.91	0.00	0.17	0.00	0.05	0.12	0.07	0.00	0.08
	Pollution	1.00	0.68	0.00	0.11	0.00	0.07	0.04	0.03	0.00	0.03

Table E.30 Risk-Based Ranking - USCG Wide Aggregation, U.S. Flag, Casualty Frequency Weighting

Service	Level III Intervention Strategy									
	Cargo/ Poll.	Steering/ Nav.	Documents/ Paperwork	Drills/ Human Factors	Auxiliary Sys.	Power Plant	Fire Prevention	Hull	Lifesaving	Other
Freight	0.36	0.58	0.00	1.00	0.00	0.12	0.05	0.15	0.00	0.07
Passenger	0.14	1.00	0.00	0.29	0.00	0.15	0.07	0.10	0.00	0.04
Tanker	0.63	0.72	0.00	1.00	0.00	0.15	0.04	0.22	0.00	0.08

Table E.31 Risk-Based Ranking - USCG Wide Aggregation, Foreign Flag, Casualty Frequency Weighting

Service	Level III Intervention Strategies									
	Cargo/ Poll.	Steering/ Nav.	Documents/ Paperwork	Drills/ Human Factors	Auxiliary Sys.	Power Plant	Fire Prevention	Hull	Lifesaving	Other
Freight	1.00	0.89	0.00	0.13	0.00	0.08	0.03	0.08	0.00	0.06
Passenger	0.33	0.21	0.00	1.00	0.00	0.04	0.08	0.00	0.00	0.00
Tanker	1.00	0.71	0.00	0.13	0.00	0.04	0.06	0.04	0.00	0.05

Table E.32 MI Cases: U.S. Flag, Annual Resource Hours and Casualties

Table E.32

MI Cases: U.S. Flag

ANNUAL Resource Hours (1989-1993), ANNUAL Casualties (1991-1993)

Resource Hours in Thousands per ANNUM, Casualties in Numbers per ANNUM

	ALL Services		PASSENGER		FREIGHT		TANK	
HULL Hours	237.60		39.60		116.20		81.80	
MACH Hours	158.40		27.80		80.00		50.60	
ADMIN Hours	233.80		43.20		112.00		78.20	
Number D&M	8.00		1.00		6.33		0.67	
Number Injured	180.00		20.67		111.00		48.33	
Number Pollutions	65.00				32.33		32.67	
Number of Vessels	951		147		503		301	

Note:

a. Pollution for only Freighters and Tankships.

Table E.33 MI Cases: U.S. Flag, Percent Change in Expected Deaths and Missing For A 1% Increase in Resource Hours

Table E.33

MI Cases: U.S. Flag

% Change in Expected DEATHS & MISSING With a 1% INCREASE in Resource Hours

Based on Results in Tables E.2

	ALL Services		PASSENGER		FREIGHT		TANK	
HULL Hours	-1.47		-0.22		-1.17		-0.92	
MACH Hours	-0.91		-0.23		-0.33		-4.00	
ADMIN Hours	-1.46		-0.28		-0.68		-1.94	

Note:

a. In order to compute standard errors, divide these figures by corresponding T-values in Table E.2

Table E.34 MI Cases: U.S. Flag, Percent Change in Expected Injuries For A 1% Increase in Resource Hours

Table E.34

MI Cases: U.S. Flag

% Change in Expected INJURIES With a 1% INCREASE in Resource Hours

Based on Results in Tables E.3

	ALL Services		PASSENGER		FREIGHT		TANK	
HULL Hours	-0.27		0.08		-0.27		-1.46	
MACH Hours	-0.33		0.01		-0.24		-0.79	
ADMIN Hours	-0.24		0.05		-0.33		-1.10	

Note:

a. In order to compute standard errors, divide these figures by corresponding T-values in Table E.3

Table E.35 MI Cases: U.S. Flag, Percent Change in Expected Pollution Occurrences For A 1% Increase in Resource Hours

Table E.35

MI Cases: U.S. Flag

% Change in Expected POLLUTION OCCURRENCES With a 1% INCREASE in Resource Hours

Based on Results in Tables E.4

	ALL Services		PASSENGER		FREIGHT		TANK	
HULL Hours	-0.16				-0.05		-0.13	
MACH Hours	-0.14				-0.05		-0.09	
ADMIN Hours	-0.17				-0.04		-0.15	

Note:

- a. In order to compute standard errors, divide these figures by corresponding T-values in Table E.4

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- 5 MS 0720 T. A. Wheeler, 6626
- 1 MS 0744 R. G. Cox, 6403
- 5 MS 0899 Technical Library, 13414
- 1 MS 0619 Print Media, 12615
- 1 MS 9018 Central Technical Files, 8523-2
- 2 MS 0100 Document Processing for DOE/OSTI, 7613-2