Determinants of The Severity of Cruise Vessel Accidents

Wayne K. Talley [a,*], Di Jin [b], Hauke Kite-Powell [b]

[a] Maritime Institute, Department of Economics, Old Dominion University, Norfolk, VA 23529, USA

[b] Marine Policy Center, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA

[*] Corresponding author. Tel: +1-757-683-3534; fax: +1-757-683-5639.
E-mail address: wktalley@odu.edu (W.K. Talley).

Abstract

This study investigates determinants of the property damage and injury severities of cruise vessel accidents. Detailed data of individual cruise vessel accidents for the 11-year time period 1991-2001 that were investigated by the U.S. Coast Guard were used to estimate cruise-vessel accident property damage and injury severity equations. The estimation results suggest that cruise vessel damage cost per vessel gross ton is greater for: allision, collision, equipment-failure, explosion, fire, flooding, and grounding cruise vessel accidents than for other types of accidents and a human cause. The accident injury severity is greater for ocean cruise than for inland waterway and harbor/dinner cruise vessel accidents and a human cause. The unit damage cost of $207 for explosion accidents is greater than that for other types of accidents. If the accident is caused by a human factor, the probability of non-fatal and fatal injuries increases by 0.0877 and 0.0077, respectively.

Keywords: Cruise vessels, Vessel accidents, Property damage, Injury

1. Introduction

The study investigates the determinants of property damage and injury severities of cruise vessel accidents. All three types of cruise vessels (ocean, inland waterway, and harbor/dinner) are considered in the investigation. Is the severity of a cruise vessel accident more likely to be greater for a certain type of cruise vessel, vessel accident, vessel characteristic, operating phase, weather/visibility condition, waterway, vessel propulsion, hull construction, and accident cause? The results of the investigation will be useful for policymakers that regulate the safety of cruise vessels, insurance companies that insure cruise vessels, managers of cruise vessel services and passengers in selecting cruise vessel services.

2. The model

The DAMAGE SEVERITY incurred by a cruise vessel accident is measured by the accident's real property damage cost per vessel gross ton. DAMAGE SEVERITY is expected to vary with the type of cruise vessel (CRUISETYPE), type of vessel accident (ACDTYPE), vessel characteristics (VESCHAR), vessel operation phase (VESOPER), weather/visibility conditions (WEATVIS), type of waterway (WATTYPE), type of vessel propulsion (PROPTYPE), type of vessel hull construction (HULLTYPE), and cause of vessel accident (CAUSE), i.e.,

$$\text{DAMAGE SEVERITY} = f(\text{CRUISETYPE, ACDTYPE, VESCHAR, VESOPER, WEATVIS, WATTYPE, PROPTYPE, HULLTYPE, CAUSE}) \quad (1)$$

The type of cruise vessel includes an ocean cruise (OCRUISE), inland waterway cruise (ICRUISE) and harbor/dinner cruise (HCRUISE). Damage to vessels and other property (i.e., surrounding property) are expected to be greater for underway inland waterway cruise and harbor/dinner cruise vessels than for ocean cruise vessels.

The type of accident includes an allision[1] (ALLISION), collision (COLLISION), equipment-failure (EQUIPFAIL), explosion (EXPLOS), fire (FIRE), flooding (FLOOD), grounding (GROUND), and a breakaway, capsize or sinking accident. The DAMAGE SEVERITY incurred by a vessel accident is expected to be greater for allision and collision vessel accidents given the speed of impact. Otherwise, the a priori relationship between type of accident and DAMAGE SEVERITY is indeterminate.

Vessel characteristics include vessel size (VSIZE), vessel age (VAGE) and whether the vessel is a U.S. flag vessel (USFLAG). The a priori sign of the relationship between DAMAGE SEVERITY and vessel size is indeterminate. Although larger vessels are expected to be more seaworthy (e.g., less susceptible to adverse weather), it is unclear once an accident occurs whether they will be more or less susceptible to damage than smaller vessels. The a priori sign of the relationship between DAMAGE SEVERITY and vessel age is positive, since vessel structural failure is expected to increase with age. A negative relationship is expected between DAMAGE SEVERITY and USFLAG, since the U.S. is a nation among nations with the highest vessel safety standards.

A vessel's operation phase is described by whether the vessel was moored or docked (MOORDOCK), anchored (ANCHOR), towed (TOW), underway (UNDERWAY) or adrift at the time of the accident. Underway vessels are expected to incur greater DAMAGE SEVERITY than moored, anchored and docked, or adrift vessels.

Weather is differentiated by whether high winds (HIGHWINDS), precipitation (PRECIP) and/or cold temperatures (COLD) exist at the time of the accident. Visibility is

---

[1] An allision accident occurs when a vessel strikes a stationary object (not another vessel) on the water surface. A collision accident occurs when a vessel strikes or was struck by another vessel on the water surface. A grounding accident occurs when the vessel is in contact with the sea bottom or a bottom obstacle.

differentiated by whether the visibility was poor (POORVISIB) and by time of day, nighttime (NIGHT) versus daytime. Although adverse weather and visibility are expected to increase the risk of a vessel accident, their impact on vessel-accident damage cost incurred is unclear.

The type of waterway includes a harbor (HARBOR), river (RIVER), coastal (COAST), ocean (OCEAN), lake (LAKE) or a bay waterway. The a priori relationship between DAMAGE SEVERITY and type of waterway is unclear. Although a vessel is more likely to have an accident in the waterway where its service is concentrated, it is unclear whether the accident will incur greater DAMAGE SEVERITY in this waterway.

Propulsion for a cruise vessel includes diesel (DIESEL), gasoline (GAS), and turbine (TURBINE). It is unclear, however, which of these propulsion sources are expected to result in greater DAMAGE SEVERITY. A cruise vessel's hull may be constructed with aluminum (ALUM), fiberglass (FIBERG), steel (STEEL) or wood (WOOD). Since steel is the strongest of these materials, it is expected that a vessel constructed with steel will incur less DAMAGE SEVERITY, all else held constant.

The initial cause of a vessel accident may be a human (HUMAN) cause as opposed to an environmental or vessel cause.[2] Even though most vessel accidents are caused by human error, it is unclear, however, which cause will result in greater DAMAGE

---

[2] Examples of human causes of vessel accidents as classified by the U.S. Coast Guard include stress, fatigue, carelessness, operator error, lack of training, error in judgement, lack of knowledge, inadequate supervision, psychological impairment and intoxication. Examples of environmental causes include adverse weather, debris, shoaling, submerged object and adverse current/sea condition. Examples of vessel causes include corrosion, dragging anchor, stress fracture, fouled propeller, steering failure, propulsion failure, auxiliary power failure and inadequate controls/displays/lighting. For further discussion of human and other causes of vessel accidents, see Abrams (1996), Millar (1980) and Staff (1998).

SEVERITY.

Replacing the explanatory variables in equation (1) with their measurement variables and then rewriting, one obtains the DAMAGE SEVERITY reduced-form equation:

DAMAGE SEVERITY = *F*(OCRUISE,ICRUISE,HCRUISE,ALLISON,
COLLISION,EQUIPFAIL,EXPLOS,FIRE,FLOOD,GROUND,
VSIZE,VAGE,USFLAG,MOORDOCK,ANCHOR,TOW,
UNDERWAY,HIGHWINDS,PRECIP,COLD, POORVISIB,
NIGHT,HARBOR,RIVER,COAST,OCEAN,LAKE,DIESEL,
GAS,TURBINE,ALUM,FIBERG,STEEL,WOOD,HUMAN) (2)

INJURY SEVERITY in a cruise vessel accident is expressed as a function of its DAMAGE SEVERITY, type of cruise vessel (CRUISETYPE), type of vessel accident (ACDTYPE), vessel characteristics (VESCHAR), vessel operation phase (VESOPER), weather/visibility conditions (WEATVIS), type of waterway (WATTYPE), type of vessel propulsion (PROPTYPE), type of vessel hull construction (HULLTYPE), and cause of vessel accident (CAUSE), i.e.,

INJURY SEVERITY = *g*(DAMAGE SEVERITY, CRUISETYPE, ACDTYPE,
VESCHAR,VESOPER,WEATVIS,WATTYPE,
PROPTYPE, HULLTYPE, CAUSE) (3)

DAMAGE SEVERITY should have a non-negative effect on INJURY SEVERITY given that a damaged vessel does not necessarily result in injured occupants. Among types of accidents, allision and collision accidents are expected to incur more injuries. Also, more injuries are expected to occur when precipitation weather and poor visibility exist. The a priori relationships between INJURY SEVERITY and type of cruise vessel, vessel characteristics, vessel operation phase, type of waterway, type of propulsion, type of hull construction, and cause of accident are unclear.

Replacing the variables in equation (3) by the variables used to measure them and rewriting, one obtains the INJURY SEVERITY reduced-form equation:

INJURY SEVERITY,= *G*(DAMAGE SEVERITY,OCRUISE,ICRUISE,HCRUISE, ALLISON,COLLISION,EQUIPFAIL,EXPLOS,FIRE,FLOOD, GROUND,VSIZE,VAGE,USFLAG, MOORDOCK,ANCHOR,TOW, UNDERWAY,HIGHWINDS,PRECIP,COLD,POORVISIB,NIGHT, HARBOR,RIVER,COAST,OCEAN,LAKE,DIESEL,GAS,TURBINE, ALUM,FIBERG,STEEL,WOOD,HUMAN) (4)

3. Data

Equations (2) and (4) are estimated utilizing detailed data of individual cruise vessel accidents that were investigated by the U.S. Coast Guard during the 11-year time period 1991-2001 and extracted from the U.S. Coast Guard Marine Safety Management System (MSMS) database. Five MSMS data tables were merged to obtain the data set for this study. The five data tables include: the Marine Casualty and Pollution Master Table (cirt), the Marine Casualty Vessel Supplement Table (civt), the Vessel Identification Table (vidt), the Marine Casualty Weather Supplement Record (cwxt), and the Marine Casualty Causal Factors Table (ccft). Vessel accidents of foreign flag vessels occurred in U.S. waters; those of U.S. flag vessels are not restricted to any body of water, although most occurred in U.S. waters.

The DAMAGE SEVERITY incurred by a cruise vessel accident is measured by the accident's real property damage cost per cruise vessel gross ton and was obtained by converting the nominal property damage costs using the U.S. Producer Price Index for all commodities. Property damage costs include damage costs to the vessel itself, its cargo and contents, and other-property damage. These costs have been or will be incurred to restore damaged vessels, cargo and contents, and other property to their service and physical conditions that existed prior to a cruise vessel accident. They are actual or estimated damage costs provided by owners to Coast Guard investigating officers. Cost estimates are considered to be accurate subject to verification by investigating officers. Damages costs to vessels do not include the cost of salvage, cleaning, gas freeing, dry-docking or demurrage.[3] Other-property damage costs in a cruise vessel accident is a catchall for other vessel-accident related damages, i.e., damages other than those incurred by vessels and their cargo and contents, not including damage to the environment. Examples include damages to pier structures and waterfront facilities.

Variables used in the equation estimations, their specific measurements, and descriptive statistics (mean and standard deviation) appear in Table 1. The mean statistic for the dependent variable DAMAGE SEVERITY reveals that a cruise vessel accident incurs $37 (on average) in property damage costs per vessel gross ton. The mean statistics for the explanatory variables reveal that 58.8, 22.1, and 19.1% of the cruise vessel accidents involved ocean cruise, inland waterway cruise, and harbor/dinner cruise vessels, respectively. The average size and age of a cruise vessel involved in an accident is 22,182 gross tons and 15.6 years. 87.3 and 92.1% of the accidents occurred when cold weather and poor visibility existed. A human factor was the initial cause of 40.3% of the accidents.

4. Estimation procedures

Given that a vessel accident does not necessarily incur damage, some of the observations of the dependent variable DAMAGE SEVERITY may be zero. If so, the distribution of DAMAGE SEVERITY observations will be left-censored. Consequently, parameter estimates for equation (2) obtained by using ordinary least squares, which ignores censoring, may be biased. Such bias is avoided by utilizing tobit regression analysis which explicitly accounts for censored dependent variables.[4]

Given the absence of information on INJURY SEVERITY, injury severity is

[3] Demurrage is a charge by a carrier for the detention of equipment and cargo beyond the free period which is allowed for loading, unloading or other purposes.

[4] For a discussion of tobit regression, see Greene (1997).

defined as a latent variable INJURY SEVERITY_{LV}, where

$$\text{INJURY SEVERITY}_{LV} = f(\beta' x) + \varepsilon \tag{5}$$

and x represents the above set of hypothesized independent variables, β is a vector of parameter coefficients to be estimated, and ε is a normally distributed error term with zero mean and unit variance. Although we cannot observe INJURY SEVERITY_{LV}, we do observe the ordinal injury severity variable *IS* (taking the value of 0, 1, or 2) which is positively related to injury severity such that

$$\begin{aligned} IS &= 0 \quad \text{INJURY SEVERITY}_{LV} \leq 0 \\ IS &= 1 \quad 0 < \text{INJURY SEVERITY}_{LV} \leq \mu \\ IS &= 2 \quad \mu < \text{INJURY SEVERITY}_{LV} \end{aligned} \tag{6}$$

where μ is an estimable threshold parameter that distinguishes the injury severity of a cruise vessel accident, where the injury severity consists of non-fatal injuries (*IS*=1) and fatal injuries (*IS*=2). If *IS*=0, there are no injuries. Given the distribution assumptions on ε, the model defined in (6) is an ordered probit model with choice probabilities (Greene, 1997):

$$\begin{aligned} \Pr(IS = 0) &= 1 - \Phi(\beta' x) \\ \Pr(IS = 1) &= \Phi(\mu - \beta' x) - \Phi(-\beta' x) \\ \Pr(IS = 2) &= 1 - \Phi(\mu - \beta' x) \end{aligned} \tag{7}$$

$\mu > 0$ to insure that all probabilities are positive.

Possible estimation bias from omission of relevant explanatory variables is addressed by including Coast Guard District, yearly and monthly binary variables (see Table 1) in the estimations. The ten US Coast Districts are represented by the binary variable DISTj, where j = 1, 2, 5, 7, 8, 9, 11, 13, 14, and 17. The 1st Coast Guard District covers the New England and New York Atlantic coast; the 2nd District covers the Midwest; the 5th District, the Mid-Atlantic coast (southern New Jersey to North Carolina); the 7th District, the Southern Atlantic coast (South Carolina to Florida); the 8th District, the Gulf coast; the 9th District, the Great Lakes; the 11th District, the California coast; the 13th District, the Pacific northwest coast; the 14th District, Hawaii; and the 17th District, Alaska.

Estimation bias from the inclusion of DAMAGE SEVERITY as an explanatory variable in the estimation of the INJURY $SEVERITY_{LV}$ equation is addressed by using the instrumental-variable estimation technique. DAMAGE SEVERITY is the dependent variable in equation (2) and thus is assumed to have an error term. It is expected that this error term will be correlated with the error term in the INJURY $SEVERITY_{LV}$ equation, thereby resulting in estimation bias for the latter. The instrumental-variable estimation technique involves finding a variable that is highly correlated with DAMAGE SEVERITY, but at the same time uncorrelated with the error term of INJURY $SEVERITY_{LV}$. For this paper, this variable (or instrument) is obtained by regressing DAMAGE SEVERITY on all explanatory variables and using the estimated DAMAGE SEVERITY variable from this equation as the instrumental variable for DAMAGE SEVERITY.

5. Estimation results

Table 2 reports the results from the estimations of equations (2) and (4) – tobit estimation results for the DAMAGE SEVERITY equation and ordered probit estimation results for the INJURY $SEVERITY_{LV}$ equation. The estimation results for statistically significant explanatory variables, constant terms, and Coast Guard District and monthly binary variables appear in Table 2.

Focusing initially upon the DAMAGE SEVERITY results, it can be seen that the model fits the data well. The chi-square statistic is 39.0, exceeding the 20.09 critical value necessary for significance at the 0.01 level for 8 degrees of freedom. The coefficients of the type of accident variables suggest that allision, collision, equipment-failure, explosion, fire, flooding, and grounding accidents incur more cruise vessel-accident damage cost per vessel gross ton than breakaways and other types of cruise vessel accidents. Also, the unit damage cost is greater when the cruise vessel accident is caused by a human factor as opposed to vessel and environmental factors.

For the ordered-probit injury severity equation estimate, the chi-square statistic is large and statistically significant at the 0.01 level. The estimation results suggest that injury severity is greater for ocean cruise than for inland waterway and harbor/dinner cruise vessel accidents, but less for allision, equipment-failure, and fire vessel accidents than for other types of vessel accidents. Injury severity is greater when the vessel's hull is constructed with steel. As for DAMAGE SEVERITY, the injury severity is greater when the cruise vessel accident is caused by a human factor as opposed to vessel and environmental factors. The estimation results also suggest that cruise vessel accident injury severity is greater in Coast Guard Districts 2 (the Midwest) and 8 (the Gulf Coast). Note that the instrumental variable for DAMAGE SEVERITY is insignificant and thus does not appear in Table 2. Recall that to insure positive probabilities, the threshold parameter μ must be positive. As reported in Table 2, the estimate of this parameter is positive and highly significant.

6. Marginal effects

Unfortunately, the tobit coefficients found in Tables 2 do not measure the correct regression coefficients for non-zero observations of the dependent variable. However, these coefficients can be adjusted to obtain such measures. McDonald and Moffit (1980) show that the change in the dependent variable (for its observations above a limit such as zero) from a change in an explanatory variable in a tobit equation can be measured as the product of the explanatory variable's tobit coefficient and the adjustment factor "*A*":

$$A = \{1 - [zf(z)/F(z)] - [f(z)^2/F(z)^2]\}, \qquad (8)$$

where, *z* represents an evaluation (at the means of the explanatory variables) of the tobit equation divided by the equation's standard error; $f(z)$ is the unit normal density; and $F(z)$ is the cumulative normal distribution function. We refer to the product of "*A*" and a given tobit coefficient as the latter's "adjusted tobit coefficient".

The adjusted tobit coefficients that correspond to the tobit coefficients in Table 2 are found in Table 3. These coefficients indicate that the vessel-accident damage cost per vessel gross ton for cruise vessels is $207and $62 more for explosion and grounding accidents, respectively, than for other types of cruise vessel accidents.

Although the signs of the estimated ordered probit coefficients provide information on whether changes in given explanatory variables increase or lower the injury severity of a cruise vessel accident, they do not provide information on the extent to which the underlying injury severity probabilities change. For example, what is the impact of changes in the explanatory variables upon the probability of a cruise vessel accident sustaining no injuries (IS = 0) versus the probability of sustaining non-fatal injuries (IS = 1).

For the ordered probit severity model, the marginal probability effects are:

$$\begin{aligned} \partial \Pr(IS = 0)/\partial x_j &= -\phi(\beta' x)\partial(\beta' x)/\partial x_j \\ \partial \Pr(IS = 1)/\partial x_j &= [\phi(-\beta' x) - \phi(\mu - \beta' x)]\partial(\beta' x)/\partial x_j \\ \partial \Pr(IS = 2)/\partial x_j &= \phi(\mu - \beta' x)\partial(\beta' x)/\partial x_j \end{aligned} \tag{9}$$

where ϕ is the standard normal density function. When $\beta' x$ is a linear function of x_j , the partial derivative $\partial(\beta' x)/\partial x_j$ is simply β_j , the coefficient of the explanatory variable x_j.

Suppose that an increase in x_j increases injury severity. Then the coefficient of x_j is positive. Thus via equation (9), an increase in x_j increases the probability of the highest injury severity category, IS = 2, and decreases the probability of the lowest injury severity category, IS = 0. However, we don't know the effect of x_j upon the probability of the injury severity category, IS = 1. This probability depends upon the extent to which some fatal-injury cruise vessel accidents shift into lower-injury categories and the extent to which some non-fatal-injury accidents shift into the no-injury category. This is seen in equation (9) by the weighted difference in the two standard normal density functions. Table 4 provides estimates of these marginal probabilities for the explanatory variables found in Table 2.

The estimated marginal probabilities in Table 4 indicate that if a cruise vessel accident involves an ocean cruise vessel, the probability that the vessel will incur non-fatal and fatal injuries increases by 0.3750 and 0.0330, respectively. Among types of cruise vessel accidents, an equipment-failure accident has the highest probability of incurring no injuries, i.e., a marginal probability of 0.8380. Among Coast Guard districts, cruise vessel accidents in District 2 have the highest probabilities of incurring non-fatal and fatal injuries, i.e., probabilities of 0.3006 and 0.0264.

7. Conclusion

This study has investigated determinants of the property damage and injury severities of cruise vessel accidents. The three types of cruise vessels – ocean, inland waterway and harbor/dinner – were considered. Detailed data of individual cruise vessel accidents for the 11-year time period 1991-2001 that were investigated by the U.S. Coast Guard were used to estimate cruise-vessel accident property damage and injury severity equations. The former severity equation was estimated utilizing tobit regression and the latter utilizing ordered probit.

The cruise vessel-accident damage cost per vessel gross ton of $207 for explosion accidents is greater than that for any other type of accident. This unit cost is expected to be $47 more if the accident is caused by a human factor than by vessel and environmental factors. Ocean as opposed to inland waterway and harbor/dinner cruise vessel accidents have the highest probabilities of incurring non-fatal and fatal injuries. If the accident is caused by a human factor, the probability of non-fatal and fatal injuries increases by 0.0877 and 0.0077, respectively.

References

Abrams, A., 1996. New rules put focus on human factors. Journal of Commerce, May 2, 8B.

Greene, W.H., 1997. Econometric Analysis, 3rd Edition, Prentice Hall, Upper Saddle River, NJ.

Millar, I.C., 1980. The need for a structure policy towards reducing human-factor errors in marine accidents. Maritime Policy and Management 6, 9-15.

McDonald, J.F., and Moffitt, R.A., 1980. The uses of tobit analysis. Review of Economics and Statistics 62, 318-321.

Staff, 1998. Human error causes most sea accidents. Journal of Commerce, April 7, 5A.

Table 1
Variable definitions and descriptive statistics

Variable	Measurement	Mean	Std. Dev.
Dependent Variable			
DAMAGE SEVERITY	real vessel-accident damage cost per vessel gross ton	37.23	201.5
IS	0 if no vessel-accident injuries 1 if non-fatal vessel-accident injuries 2 if fatal vessel-accident injuries	0.445	0.627
Explanatory Variable			
Type of cruise vessel			
OCRUISE	1 if an ocean cruise vessel, 0 otherwise	0.588	0.493
ICRUISE	1 if an inland waterway cruise vessel, 0 otherwise	0.221	0.416
HCRUISE	1 if a harbor/dinner cruise vessel, 0 otherwise	0.191	0.394
Type of accident [a]			
ALLISION	1 if an allision vessel accident, 0 otherwise	0.085	0.279
COLLISION	1 if a collision vessel accident, 0 otherwise	0.045	0.209
EQUIPFAIL	1 if an equipment-failure vessel accident, 0 otherwise	0.261	0.440
EXPLOS	1 if an explosion vessel accident, 0 otherwise	0.006	0.078
FIRE	1 if a fire vessel accident, 0 otherwise	0.085	0.279
FLOOD	1 if a flooding vessel accident, 0 otherwise	0.009	0.095
GROUND	1 if a grounding vessel accident, 0 otherwise	0.106	0.308
Vessel characteristics			
VSIZE	vessel size in gross tons	22182	26879
VAGE	vessel age in years	15.55	14.34
USFLAG	1 if a US flag vessel, 0 otherwise	0.427	0.495
Vessel operation phase			
MOORDOCK	1 if vessel is moored or docked, 0 otherwise	0.185	0.389
ANCHOR	1 if vessel is anchored, 0 otherwise	0.152	0.122
TOW	1 if vessel is towed, 0 otherwise	0.003	0.055
UNDERWAY	1 is vessel is underway, 0 otherwise	0.494	0.501
Weather/visibility conditions			
HIGHWINDS	1 if high winds exist (greater than 20 knots), 0 otherwise	0.021	0.144

PRECIP	1 if precipitation weather, 0 otherwise	0.030	0.172
COLD	1 if cold temperature (less than 32 Fahrenheit degrees), 0 otherwise	0.873	0.334
POORVISIB	1 if poor visibility, 0 otherwise	0.921	0.270
NIGHT	1 if nighttime, 0 otherwise	0.024	0.154
Type of waterway [b]			
HARBOR	1 if a harbor, 0 otherwise	0.109	0.312
RIVER	1 if a river, 0 otherwise	0.264	0.441
COAST	1 if a coastal waterway, 0 otherwise	0.236	0.425
OCEAN	1 if an ocean, 0 otherwise	0.176	0.381
LAKE	1 if a lake, 0 otherwise	0.009	0.095
Type of propulsion [c]			
DIESEL	1 if vessel is under diesel propulsion, 0 otherwise	0.736	0.441
GAS	1 if vessel is under gasoline propulsion, 0 otherwise	0.003	0.055
TURBINE	1 if vessel is under turbine propulsion, 0 otherwise	0.130	0.337
Type of hull construction [d]			
ALUM	1 if aluminum hull construction, 0 otherwise	0.061	0.239
FIBERG	1 if fiberglass hull construction, 0 otherwise	0.021	0.144
STEEL	1 if steel hull construction, 0 otherwise	0.321	0.468
WOOD	1 if wood hull construction, 0 otherwise	0.036	0.187
Cause of accident			
HUMAN	1 if a vessel accident was initially caused by a human factor, 0 otherwise	0.403	0.491
Coast Guard district			
DIST1	1 if district one, 0 otherwise	0.112	0.316
DIST2	1 if district two, 0 otherwise	0.124	0.330
DIST5	1 if district five, 0 otherwise	0.027	0.163
DIST7	1 if district seven, 0 otherwise	0.361	0.481
DIST8	1 if district eight, 0 otherwise	0.073	0.260
DIST9	1 if district nine, 0 otherwise	0.030	0.172
DIST11	1 if district eleven, 0 otherwise	0.067	0.250
DIST13	1 if district thirteen, 0 otherwise	0.027	0.163
DIST14	1 if district fourteen, 0 otherwise	0.052	0.221
DIST17	1 if district seventeen, 0 otherwise	0.127	0.334
Year			
Y91	1 if year 1991, 0 otherwise	0.006	0.078
Y92	1 if year 1992, 0 otherwise	0.042	0.202
Y93	1 if year 1993, 0 otherwise	0.070	0.255

Y94	1 if year 1994, 0 otherwise	0.052	0.221
Y95	1 if year 1995, 0 otherwise	0.088	0.284
Y96	1 if year 1996, 0 otherwise	0.182	0.386
Y97	1 if year 1997, 0 otherwise	0.112	0.316
Y98	1 if year 1998, 0 otherwise	0.142	0.350
Y99	1 if year 1999, 0 otherwise	0.130	0.337
Y00	1 if year 2000, 0 otherwise	0.100	0.300
Y01	1 if year 2001, 0 otherwise	0.076	0.265
Month			
M1	1 if January, 0 otherwise	0.064	0.244
M2	1 if February, 0 otherwise	0.070	0.255
M3	1 if March, 0 otherwise	0.082	0.275
M4	1 if April, 0 otherwise	0.067	0.250
M5	1 if May, 0 otherwise	0.094	0.292
M6	1 if June, 0 otherwise	0.109	0.312
M7	1 if July, 0 otherwise	0.130	0.337
M8	1 if August, 0 otherwise	0.106	0.308
M9	1 if September, 0 otherwise	0.091	0.288
M10	1 if October, 0 otherwise	0.085	0.279
M11	1 if November, 0 otherwise	0.055	0.227
M12	1 if December, 0 otherwise	0.048	0.215

[a] Other types of accidents in our data include breakaways and sinkings.
[b] Our data also include the category “other waterways.”
[c] Other types of propulsion in our data include sail and “other propulsion type.”
[d] Other types of hull construction in our data include plastic and “other hull material.”

Table 2
Cruise vessel-accident equation estimates [a]

Explanatory Variable	DAMAGE SEVERITY [b]	INJURY SEVERITY$_{LV}$ [c]
Type of cruise vessel		
OCRUISE	---	1.3134 (4.59)
Type of accident		
ALLISION	434.5 (3.94)	-1.5517 (-4.62)
COLLISION	596.5 (4.02)	---
EQUIPFAIL	345.7 (3.31)	-2.6979 (-6.63)
EXPLOS	758.6 (3.25)	---
FIRE	594.2 (4.49)	-1.8446 (-5.00)
FLOOD	432.3 (2.06)	---
GROUND	226.5 (1.90)	---
Type of hull construction		
STEEL	---	0.4991 (1.78)
Cause of accident		
HUMAN	170.8 (2.43)	0.3071 (1.82)
Coast Guard district		
DIST2	---	1.0528 (2.71)
DIST8	---	0.6344 (1.89)
Month		
M11	---	-0.9860 (-2.51)
Constant	-521.8 (5.12)	-0.8956 (-3.03)
Ordered Probit Parameter, μ # of Observations	-- 147	1.6446 (11.06) 330
Chi-Square Statistic	39.0	183.2

[a] *t* statistics are in parentheses.
[b] tobit regression estimate.
[c] ordered probit estimate.

Table 3
Marginal damage effects of cruise vessel accidents

Explanatory Variable	DAMAGE SEVERITY
Type of accident	
ALLISION	118.3
COLLISION	162.4
EQUIPFAIL	94.14
EXPLOS	206.6
FIRE	161.8
FLOOD	117.7
GROUND	61.69
Cause of accident	
HUMAN	46.53

Table 4
Marginal injury-severity probabilities of cruise vessel accidents

Explanatory Variable	*IS* = 0 [a]	*IS* = 1 [b]	*IS* = 2 [c]
OCRUISE	-0.4080	0.3750	0.0330
ALLISION	0.4820	-0.4430	-0.0389
EQUIPFAIL	0.8380	-0.7703	-0.0677
FIRE	0.5730	-0.5267	-0.0463
STEEL	-0.1550	0.1425	0.0125
HUMAN	-0.0954	0.0877	0.0077
DIST2	-0.3270	0.3006	0.0264
DIST8	-0.1971	0.1811	0.0159
M11	0.3063	-0.2815	-0.0247

[a] Change in the probability of no injuries.
[b] Change in the probability of a non-fatal injury.
[c] Change in the probability of a fatal injury.