

**PAPER 521: Using GIS to Examine Risk-taking and
System Hazard among Rare Events**

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Abstract

This research uses GIS to examine risk-taking and system hazard associated with maritime commercial passenger ship casualties (1950-1998). Complicating the analysis of these rare events (n=532) is their wide geographic distribution. To account for important regional factors affecting maritime transportation, the water surface was divided into ten regions—Southeast Asia, Northern Europe, Southern Europe, the Caribbean, the Middle East, Asia, Eastern Africa, Northern Pacific, Northeastern United States and other—which serves to limit spatial analysis. This paper demonstrates that it is possible to resolve this issue by incorporating GIS-based spatial analysis with traditional analytic techniques.

Introduction

Heretofore, shipping disasters were commonly attributed to limited technology; “(n)avigational systems and fire protection were relatively primitive, combustion engines were prone to problems, and ship hulls were not compartmentalized” (Mueller and Adler, 1991:102). As revolutionary advances in ship design, navigation, and shipping standards occurred, unfaltering casualty rates lead to a new accident paradigm. Accident investigators and researchers alike attributed most maritime casualties to human error; formal inquiries consistently found that about 80 percent of events investigated were caused by human error on the part of shipboard operators (Lloyd’s List, 1994; Taska, 1990; Millar, 1980:9; Gardenier, 1981; and Benkert 1978). Commercial passenger ship casualties are no exception.

Recently, critics have begun to assemble evidence that suggests the accident investigation process may be somewhat biased (Taska, 1990). Presumptions on behalf of the investigators lead them to focus on the shipboard operations immediately preceding the event. Focusing exclusively on shipboard operations inevitably leads investigators to overlook, and even neglect, the role played by shore-based management that sets the conditions onboard the vessel (Tasca, 1990; Peterson, 1980).

Those criticizing the “operator error” explanation argue that it is important to take into account the context within which the master and crew maneuver, in particular, the decisions made by corporate executives (Wagenaar, 1992; Tasca, 1990; Maritime Transportation Research Board, 1976). “Unrealistic sailing schedules, staffing deficiencies, and inadequate equipment maintenance are all executive, profit-driven decisions that directly affect the operating conditions of the vessel” (Bichler-Robertson, 2001:8). Corporations that choose to maximize profit at the expense of safety, knowingly

put the lives of passengers and crew in danger; as such, these calculated decisions—corporate risk-taking—constitute corporate negligence thereby rendering the corporation criminally culpable for the casualty. (For a more detailed explanation of legal arguments about corporate negligence within a maritime transportation context please see Bichler-Robertson, 2000:25-41.)

A second plausible explanation for maritime casualties is system hazard (Perrow, 1984; Bichler-Robertson, 2000). Accidents occur within a transportation system that is affected by: the management practices of other vessel owners; procedures, practices and enforcement capacity of various maritime regulatory agencies, Port Authorities and Protection and Indemnity Clubs; international relationships and economic conditions; and, local political/economic factors (Bichler-Robertson, 2000). Added to this mix are weather conditions, hydrological features, tidal patterns, and traffic volumes that interact with the above mentioned system components to generate hazards that impact differentially on each vessel (Perrow, 1984; Bichler-Robertson, 2000).

Methodological Issues

Examining the influence of corporate risk-taking and system hazard on maritime passenger ship casualties is a formidable task in terms of sample generation, data analysis, and variable construction. Issues of sample generation affect the construction of variables and limit analytic strategies.

Sample Generation and Data Analysis

Foremost among methodological issues is that casualties are relatively *rare events*. According to Lloyd's Register of Shipping, less than one percent of world's merchant passenger fleet (vessels over 1,000 gross tons) is lost each year (US Bureau of the Census, 1978-1997). This amounts to a handful of annual casualties: to demonstrate the rarity of events, there were no total constructive losses of passenger vessels over 500 gross tons worldwide in 1985 and 1990, and only one for each year in 1992 and 1993. While accurate figures are unlikely, given the disjointed nature of recording practices, it is clear that serious passenger ship casualties are rare. Conducting a standard density, proximity or traditional statistical analysis, on a handful of events, will fail to provide any useful or credible conclusions. This necessitates a lengthy study period over a wide geographic area to capture a body of events with sufficient diversity and volume to warrant reasonable confidence in the study conclusions; however, using an extended study period raises complications for variable construction.

Variable Construction

Information required to examine the decision-making of shore-based management and system hazard over an extended period of time, does not exist in any available database. Complicating the reliability of information pertaining to risk-taking is that corporations are unlikely to make incriminating information readily available; therefore, information about risk-taking must be drawn from *publicly available sources*.

In addition, cruise vessels and long range ferries *travel through multiple regions*, each with differing levels of system hazard. Information about all of the factors associated

with system hazard is not consistently available for all regions throughout a lengthy study period. For example, research on casualties occurring in Southeast Asia must account for the creation of Bangladesh, the split of Korea, and political changes in Vietnam. These challenges required the use of proxy measures or restricting the study to a single region in order to account for major events that alter necessary data. This kind of research is most easily conducted in regions consisting predominantly of first world nations with consistent data generating agencies and stable economies. Given the importance of the maritime commercial passenger trade to other nations, in particular, developing maritime nations, restricting events to a single region would hamper the utility of research conclusions.

A narrow geographic focus would also contribute to *right hand spatial censoring* (Bichler-Robertson, 2000:115-116). Formulations of hazard typically involve some sort of risk measure. Usually it involves an accident rate from an earlier period of time, i.e. three-year rolling average of the proportion of vessels involved in a casualty for a defined geographic area. The denominator in this calculation requires information about the total number of vessels, in the designated area, that could be involved in a casualty. Vessels originating within the study area may flounder outside of the region and this event would not be captured in the analysis. Conversely, events involving vessels that originated outside the area of study many occur within the region in question. This interrelated nature of maritime transportation requires either a global perspective or narrow selection criteria—only using local ferries or cruise vessels. However, given the rarity of events, research must use a global sample generation process and construct measures that are somewhat reliable over space and time.

Overcoming Methodological Issues

To address these methodological limitations, this research involved constructing a database of casualties by piecing together bits of information from many publicly available sources: newspapers, wire services, and Lloyd's List were examined to find the initial event information—name and ownership of the vessel, location of the casualty, eyewitness testimony regarding the vessel's condition, number of people involved, and estimates of the seriousness of the event in terms of material damage and lives lost. Using the vessel's name, owner and accident location, it was possible to search Maritime Court proceedings and national accident investigation commission reports for information about factors leading up to the event, including some relevant information about the vessel's management. Next, cross-referencing the vessel's name with the listings of registries provided information about the vessel's legal capacity, major renovations, age and other pertinent details. Data were then examined against chronicles—like Norman Hooke's *Maritime Casualties 1963-1996* (1997)—for completeness and consistency.

Indicators of Corporate Negligence

For the purposes of this research, risk-taking was synonymous with corporate negligence. Within the maritime context, corporate negligence involves acts of omission or commission resulting from deliberate decision-making by those occupying structural positions within the business organization—corporate executives or managers—that renders the vessel unseaworthy, meaning it is unfit for its intended use.

As stated above, obtaining information about profit maximizing decisions is a difficult enterprise because crucial evidence is under the direct control of the organization; however, risk-taking can be ascertained through indirect measures. A number of factors are commonly accepted as being indicative of corporate attempts to maximize profit at the expense of safety including, but not limited to: registration with a flag of convenience (FOC), vessel age (over 20 years old), poor vessel maintenance, inoperable auxiliary equipment, loading beyond legal capacity, and failure to keep an accurate manifest. Indicators of each factor listed above were created (dichotomous coding where a value of one indicates presence of the feature and zero reflects absence) and summed to construct an index of risk-taking. Events with more than three points on this index are associated with high levels of potential risk-taking. (For more information about variable construction please see Appendix A).

Indicators of System Hazard

System hazard was defined as a general overarching threat posed by external or systemic elements—classification societies, Protection & Indemnity Clubs, port authorities, registries, Coast Guard, weather, traffic volume, actions of other captains, and treacherous channels—associated with the maritime passenger transportation industry, within a particular area. Given the complexity of the system, duration of the study period, and global nature of this research, it was not possible to create direct measures of each system component listed.

Six variables were combined in an additive fashion to create an index of system hazard: low enforcement capacity (GDP in constant 1993 US dollars assigned values by quartiles); exposure to hazard (voyage length in nautical miles assigned values by quartiles); the event occurred in a high traffic area (within 1.5 nm of a harbor or in a major shipping lane); the event involved a collision with another vessel (reflects density of traffic and behavior of other vessels); and, inclement weather (major storms). Similar to the index discussed above, events with three or more points on this measure are likely to be associated with high levels of system hazard. (Additional information about the construction of this variable can be found in Appendix A.)

Study Casualties

Selection criteria were kept to a minimum; all casualties between 1950 – 1998 involving cruise ships and ferries that were sailing with fare paying passengers at the time of the event were included. Vessels had to be legally certified to carry at least 10 people. Chartered fishing ships and those vessels involved in transporting refugees were not included. Events were coded by the location of the casualty, not the origin or destination. Ten regions, somewhat loosely based on United Nations classifications and volume of maritime traffic, were used: NE United States, North Pacific, Eastern Africa, Middle East, Asia, Southern Europe, Caribbean, Northwestern Europe, and Southeast Asia.

The data collection process generated 532 usable events that involved in excess of 24,000 deaths and about 6,840 serious injuries.ⁱ Despite the breadth of the study period, about 54 percent of the casualties occurred from 1988—1998 (see Table 1).ⁱⁱ Casualties were

fairly evenly split between ferries and cruise ships (54.2 and 44.7 percent respectively). Events were more likely to occur in the evening or late at night. Most of the events involved collisions, fires or groundings (28, 25 and 19 percent respectfully).

Table 1. Description of Maritime Commercial Passenger Ship Casualties, 1950 –1998.

Variables	Valid %	Variation
<i>Study Period</i>	(532)	.906
1950 – 1976	24.2	
1977 – 1987	22	
1988 – 1998	53.8	
<i>Type</i>	(472)	0.76
Ferry	54.2	
Cruise Liner	44.7	
Other	1.1	
<i>Time of Day</i>	(242)	0.933
6:01 to 14:00	21.1	
14:01 to 22:00	28.9	
22:01 to 6:00	50	
<i>Nature of Event</i>	(516)	0.94
Collision	27.7	
Fire	25.2	
Grounding	19.4	
Loading	9.3	
Mechanical	6.8	
Weather	10.3	
Other	1.4	

Notes: The figures in brackets are the number of valid cases. Variation is measured with the Index of Dispersion. The Index of Dispersion is used to illustrate the variance among nominal and ordinal variables where “0” reflects complete concentration and “1” reflects maximum variation or equal distribution.

Comparing casualty rates with those reported in official statistics demonstrates that this database development strategy generates loss estimates that are seven to 12 times higher than those reported in statistical abstracts (Bichler-Robertson, 2000:228). According to official statistics, less than one percent of the merchant passenger fleet was lost each year (1976-1993); however, this database estimates that during this time period an average of 3.2 percent of the world’s merchant passenger fleet was lost each year (Bichler-Robertson, 2000).

Geographical Analysis

Two types of analysis were conducted on this set of casualties: traditional statistical analysis including Ordinary Least Squares Multiple Regression, and a Kernel Density analysis of key areas within high frequency regions.

Traditional Statistical Analysis

Casualties were not evenly distributed across the 10 regions; Southeast Asia and Northwestern Europe had substantially more events than other areas (Table 2). This is not surprising given the heavy reliance on maritime passenger ship travel in these regions.

Table 2. Regional Distribution of Maritime Passenger Ship Casualties, 1950-1998 (N=527).

Region	Valid Percent
SE Asia	21.8
NW Europe	18.4
Caribbean	8.7
S Europe	8.7
Asia	6.6
Middle East	5.3
E Africa	6.6
N Pacific	3.4
NE United States	6.6
Other	5.9

i. Characteristics of Casualties by Region

Looking at the distribution of corporate risk-taking factors within each of the four areas of casualty concentration reveals interesting patterns (Table 3). Southeast Asian casualties are about twice as likely to involve antiquated vessels (over 20 years old) that were demonstrably deficient in terms of adhering to internationally accepted safety standards. Compared to Northwestern Europe, Southeast Asian casualties are also more likely to be characterized with manifest issues; in six times as many events, the owners were unable to accurately identify the number of passengers that were on the vessel. While Southeast Asian casualties were less likely to involve vessels flagged with convenience registries, they were about 28 times more likely to involve overloading.

Table 3. Factors Reflecting a High Likelihood for Corporate Risk-Taking Associated with Commercial Passenger Ship Casualties occurring in Selected Areas Compared with the Average, 1950 – 1998.

Risk-taking Variables	High Volume		Moderate Volume		Average
	SE Asia Percent	NW Europe Percent	Caribbean Percent	S Europe Percent	
Old Boat	58.6 (70)	25.7 (74)	38.1 (42)	51.1 (45)	44.7 (407)
Private Owner	83.8 (78)	95.4 (87)	97.7 (43)	95.3 (43)	87.3 (442)
Safety Violations	70.1 (67)	41.4 (58)	40.6 (32)	42.3 (26)	52 (325)
Manifest Issues	60.4 (91)	11 (73)	31.6 (38)	34.4 (32)	30.7 (423)
Overloaded	27.9 (111)	1 (97)	8.7 (46)	2.2 (46)	9.8 (521)
FOC	7 (115)	14.4 (97)	47.8 (46)	8.7 (46)	16.5 (532)

Notes: There were: 115 events in Southeast Asia (21.8 percent of total), 97 events in Northwestern Europe (18.4 percent of casualties), 46 events in the Caribbean (8.7 percent of events) and 46 events in Southern Europe (8.7 percent of events). Figures presented are valid percents and bracketed numbers are valid cases.

Comparing moderate volume casualty areas, the most striking differences relate to the age of the vessels, overloading, and national registration. Caribbean casualties tended to involve newer vessels—most likely a reflection of the rapidly expanding US based cruise industry.ⁱⁱⁱ The strikingly high level of FOC registered vessels also reflects the impact of the Caribbean cruise industry in this region. It is important to note that all of the loading-related events involved ferries servicing the area and not the cruise industry.

System hazard is also distributed unevenly across the regions (Table 4). Comparing the two high volume areas, events are different in terms of proximity to high traffic, enforcement capacity (GDP) and voyage length (exposure to system hazard). Casualties occurring in Southeast Asia are less likely to occur in busy shipping lanes or within 1.5 nm from a major port. Examining the distribution of events in terms of associated GDP of closest nation illustrates that most events in Southeast Asia occur near nations with poor enforcement capacities. In addition, Southeast Asian events involve vessels traveling shorter distances.

Table 4. Factors Reflecting the System Hazard Associated with Commercial Passenger Ship Casualties occurring in Selected Areas Compared with the Average, 1950 – 1998.

Variables	High Volume		Moderate Volume		Average
	SE Asia Percent	NW Europe Percent	Caribbean Percent	S Europe Percent	
High Traffic Area					
Busy Shipping Lane	28.2 (110)	42.6 (94)	2.2 (46)	75.6 (45)	28 (515)
Harbor	25.2 (111)	43.6 (94)	37.0 (46)	24.4 (45)	35.4 (517)
GDP recoded					
0 – 25 quartile	0	34	26.1	0	20.3
26 – 50	5.2	60.8	50.0	54.3	38.5
51 – 75	34.8	5.2	10.9	45.7	20.7
76 – 100	60.0	0	13.0	0	20.5
Voyage Length					
0 – 25 quartile	(115)	(97)	(46)	(46)	(532)
26 – 50	23.5	28.9	10.9	4.3	24.4
51 – 75	50.4	30.9	15.2	30.4	29.3
76 – 100	22.6	26.8	52.2	15.2	19.9
Incident Weather					
Collision w/ Vessel	37.8 (111)	32.0 (97)	4.3 (46)	28.3 (46)	28.8 (521)
	17.1 (111)	18.6 (97)	13.0 (46)	15.2 (46)	18 (521)

Notes: There were: 115 events in Southeast Asia (21.8 percent of total), 97 events in Northwestern Europe (18.4 percent of casualties), 46 events in the Caribbean (8.7 percent of events) and 46 events in Southern Europe (8.7 percent of events). Figures presented are valid percents and bracketed numbers are valid cases.

Comparing Caribbean casualties to Southern European casualties shows dramatic differences. While voyage length and collision features are relatively similar, other features are opposite. Southern European casualties occur in busy shipping lanes (75.6 percent); whereas, Caribbean events occur with greater frequency near major ports. In addition, Southern European events occur near nations with moderate enforcement

capacity whereas Caribbean vessels overwhelmingly occur near nations with moderate to high enforcement capacity.

Turning to the magnitude of the casualties, Southeastern Asia is plagued with more horrific events while Northwestern Europe casualties are minor (Table 5). Contributing to this discrepancy is the polar difference in GDP. Although used here to measure enforcement capacity, GDP is also indirectly tied to search and rescue capacity. Casualties occurring on Northwestern European waterways may have the capacity to be as catastrophic but proximity to Coast Guard rescue services reduce the fatality rates, just as murder rates are linked to proximity to hospital services.

Table 5. Event Seriousness Associated with Commercial Passenger Ship Casualties occurring in Selected Areas Compared with the Average, 1950 – 1998.

Seriousness	High Volume		Moderate Volume		Average
	SE Asia Percent	NW Europe Percent	Caribbean Percent	S Europe Percent	
Minor	12.6	52.6	33.4	20.4	20.7
Moderate	15.3	22.1	23.8	45.5	34.7
Serious	12.6	14.7	21.4	20.5	15.3
Catastrophe	59.5	10.5	22.4	13.7	29.3

Notes: There were: 115 events in Southeast Asia (21.8 percent of total), 97 events in Northwestern Europe (18.4 percent of casualties), 46 events in the Caribbean (8.7 percent of events) and 46 events in Southern Europe (8.7 percent of events). Figures presented are valid percents.

Within the moderate volume category, Caribbean events are somewhat evenly split among all four categories; on the other hand, Southern European casualties are predominantly minor to moderate. (For a detailed description of the seriousness ranking see Appendix B.)

ii. Ordinary Least Squares

Ordinary Least Squares estimates illustrate the importance of examining casualties on a regional basis. All models were significant in accounting for variation; though, the percent accounted for varies.

Corporate risk-taking factors account for a significant amount of the variation in seriousness of casualties occurring in Southeast Asia (Table 6). Together the independent variables explain 64 percent of the variation in magnitude of casualties. With a standardized beta coefficient of .195, the variable measuring risk-taking is 19 times more important than the measure of system hazard. This pattern is not replicated in Northwestern Europe. While the model was significant and accounted for about 37% of the variation, neither of the independent variables—risk-taking or system hazard—were significant.

[Table 6 about here]

Table 6. OLS Regression Estimates for Commercial Passenger Ship Casualties occurring within High and Moderate Volume Areas, 1950 – 1998.

Variables	SE Asia			NW Europe			Average		
	b	SE	β	b	SE	β	b	SE	β
RISK-TAKING	.294 ^B	.105	.195	-.162	.203	-.086	.202 ^C	.06	.122 ^C
SYSTEM	-3.55E-02	.153	-.016	7.6E-02	.184	.044	.138	.075	.063
Crisis Evac	2.84 ^C	.286	.734	2.8 ^C	.497	.633	2.54 ^C	.149	.654 ^C
G/Ton	3.07E-06	.00+	.011	3.1E-06	.00+	.024	-8.8E-06	.00+	-.066
Constant	1.805 ^C	.495	/	2.213 ^C	.593	/	1.82 ^C	.238	/
F	35.44 ^C			8.60 ^C			114.99 ^C		
R ² /Adj R ²	.642/.624			.368/.326			.542/.537		
N	83			63			393		

Variables	Caribbean			S Europe		
	b	SE	β	b	SE	β
RISK-TAKING	.254	.218	.197	.190	.254	.113
SYSTEM	.248	.405	.097	.497	.276	.293
Crisis Evac	.846	.715	.197	1.4 ^B	.463	.457
G/Ton	-2.57E-05 ^A	.000	-.346	-3.0E-07	.000	-.003
Constant	2.409 ^A	1.02	/	.954	1.109	/
F	3.223 ^A			3.818 ^B		
R ² /Adj R ²	.315/.217			.345/.255		
N	32			33		

*Note the use of three 1-tailed significance levels: A = p < .05; B = p < .01; and, C = p < .001.

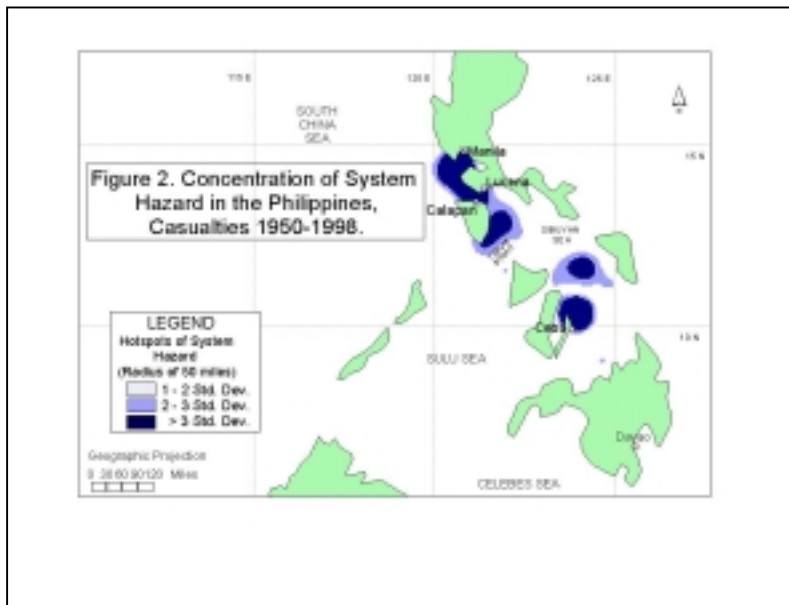
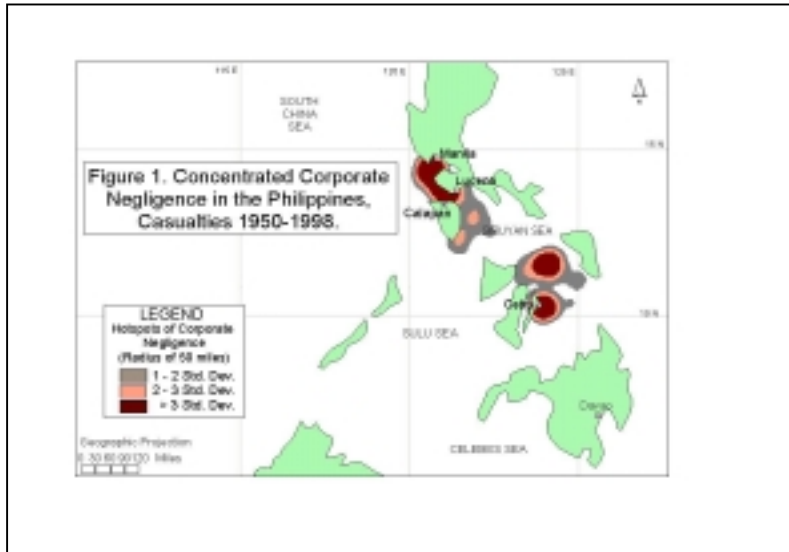
Turning to the moderate volume areas, the model remained significant and consistently accounts for over 30% of the variation; however, neither of the explanatory variables have significant effects in the Caribbean or Southern Europe (Table 6). Among Caribbean casualties, the measure of corporate risk-taking had a standardized beta coefficient that had twice the effect as system hazard; though, neither were significant. In Southern Europe this pattern was reversed and equally as insignificant.

Spatial Analysis with GIS

Two analytic procedures were applied to the areas of highest casualty concentration within each high volume region: the Philippines and the English Channel (12 and 9.6 percent of the casualties respectively). Kernel density analyses were conducted at varying scales—in miles and nautical miles—to determine where high levels of corporate risk-taking and system hazard concentrate: 50, 20 and 10-mile radius; and, 10 and five-nautical mile radius (only a couple of maps are included here). Equal interval and standard deviation were used to define categories.

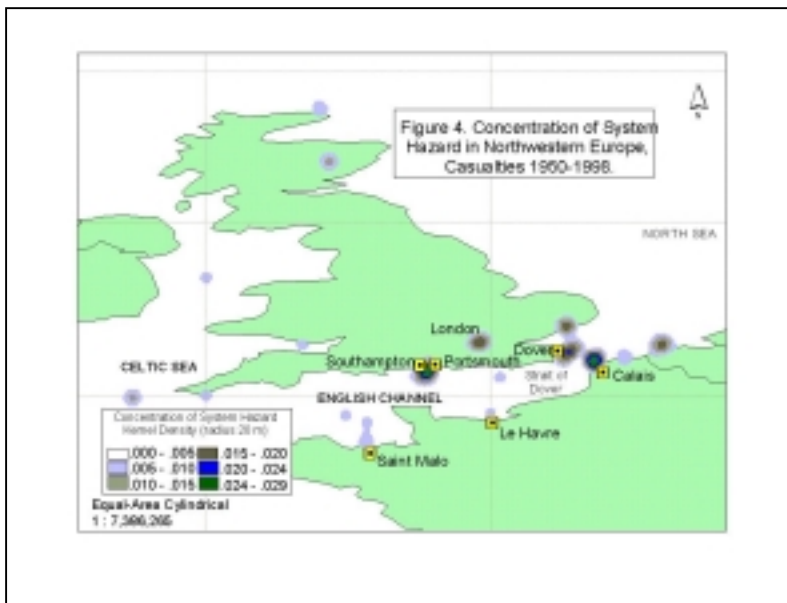
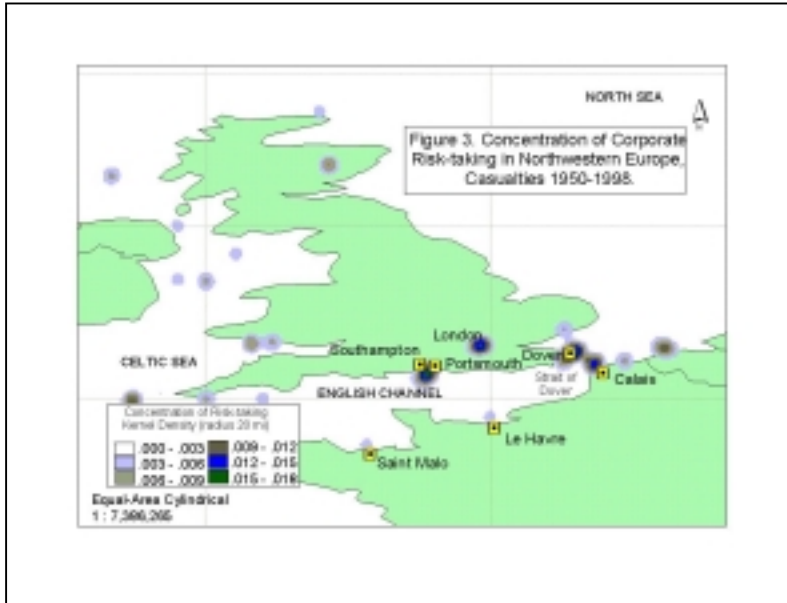
Examining the geographic distribution of corporate risk-taking and system hazard within the two high volume areas shows interesting patterns (Figures 1-4). Figure 1 shows a kernel density of corporate risk-taking with a 50-mile radius. Casualties associated with high levels of corporate risk-taking are not evenly spread throughout the area; instead, events with high scores, on the index variable reflecting corporate risk-taking, concentrate near major harbors. Events highly associated with corporate negligence tend to occur along the main shipping route between Calapan and Manila.

Additional concentrations of negligence, beyond three standard deviations, exist near to Cebu City and Masbate Island—though the crudeness of the map make it difficult to identify the exact location. System hazard concentrates in the same areas with one exception, there is another key area along the side of Midoro Island in the Tablas Strait (Figure 2). Changing the map units, radius and scale did not alter these patterns.



In the region of Northwestern Europe that was selected for closer inspection, two areas appeared to be consistently important (Figures 3 and 4). An adjusted equal area kernel density map of casualties with high levels of corporate risk-taking shows an important concentration focused on the ports of Dover and the area near Portsmouth and

Southampton. Examining the system hazard map it is clear that hazard is higher in this area and while the previously mentioned areas of concentration appear again, Calais becomes the focal point in the Strait of Dover.



Discussion

The traditional statistical analysis reported above suggested that while corporate risk-taking was a significant factor overall, it was only an important variable among casualties in Southeast Asia. Dissecting the index term we find that Southeast Asian casualties were associated with high levels of safety violations (70 percent of casualties) and overloading (30 percent). This means that had these vessels been inspected for compliance with

international shipping standards developed by the IMO prior to sailing they would have been grounded for safety violations. Equally important is the finding relating to safety violations in other areas.

While the index term of risk-taking failed to be significant in the other regions, there were unexpectedly high levels of safety violations. This is cause for concern.

The high level of deficiencies in the Caribbean—more than 40 percent of casualties—is interesting given the recent focus of US efforts to crack down on foreign flags and inspect all cruise vessels on a regular basis. This study confirms a report that summarized inspections of 193 cruise vessels sailing from US ports (137 of which were flying foreign flags): the report found a high level of safety deficiencies/violations among all vessels inspected (GAO, 1993).

European casualties showed similar rates of safety violations despite multinational efforts to improve shipping. Under the Paris MOU, vessels calling on European ports since 1982 are subject to a multinational inspection effort.^{iv} Collectively, the 18 members of the Paris MOU inspect between 85 – 95 percent of foreign merchant ships (Paris MOU, 1997). Together, these nations found that about 52.8 percent of inspections of passenger ships and ferries turned up deficiencies (Paris MOU, 1997). This is consistent with these findings.

Even within areas where corporate risk-taking was not a dominant feature, the concentration of casualties associated with high levels of risk-taking increased with proximity to major ports. System hazard also concentrated near major ports. This suggests an important interaction affect that intensifies as the distance to port decreases. More research is needed to examine this phenomenon in greater detail.

Given the importance of these findings, additional analysis were preformed to examine the level of safety violations associated with casualties occurring between pre- and post signing of the Paris MOU and the US Coast Guard report (GAO, 1993). This analysis showed no significant differences. Comparing casualties occurring between 1950 and 1981 with those occurring following the creation of the Paris MOU, there was a five percent decrease (45.5 to 40.4 percent among Northwestern European casualties and 45.5 and 40.0 percent in Southern Europe) in the number of casualties involving vessels with existing safety problems. Among Caribbean casualties, there was a ten percent increase in the number of casualties involving vessels with safety deficiencies (36.8 to 46.2 percent) when comparing pre- and post-release of the Coast Guard study; however, this change was not significant. Repeating the analysis with a four-year time lag does not improve the results. From this preliminary analysis it appears that international efforts to increase enforcement of shipping conventions, created by the International Maritime Organization and ratified by member states, have been unable to rectify the situation (Paris MOU, 1997). Additional research is needed to more carefully study the impact of these multi-national efforts.

Conclusion

Research examining corporate decision-making provides extensive evidence of corporate wrong doing in the name of profit (Punch, 1996; Keane, 1993; Mokhiber, 1988). Subversion of safety laws through cost-cutting measures equates to conscious decisions to sacrifice the safety of passengers and crew. Data challenges associated with studying rare events involving corporations can be overcome with publicly available data sources. Further, combining traditional statistical analyses with GIS-based analyses provides additional insights with important policy implications. Even within regions where corporate risk-taking was not found to be a significant explanatory factor, areas of high risk-taking concentration exist. Surprisingly, these areas of concern overlap with areas of high system hazard, suggesting an important interaction effect that intensifies with increasing proximity to major ports. This pattern was only visible through GIS and would have been overlooked if one simply relied on traditional statistics. This research demonstrates the utility of using GIS to examine rare events.

Appendix A

Below are excerpts from Bichler-Robertson (2000:106-112) that detail how variables were constructed.

i. Operationalizing the Concept of Negligent Corporate Risk-taking

Seven independent variables represent the concept of negligent corporate risk-taking these are; vessels over 20 years old (*old boats*), private ownership (*PRIVATE*), flag of convenience (*FOC*), flag of detention (*FOD*), presence of deficiencies (*safety violations*), failure to record the actual number of passengers and crew on board the vessel (*poor manifests*) and loading beyond capacity (*overloaded*). Each variable was recoded into a dichotomous variable where “1” indicates presence of the factor. Then, the variables were combined in an additive index item to represent negligent corporate risk-taking (*RISKY*). (...)

National registries considered flags of convenience in this study include those listed as convenience flags by the International Transport Workers’ Federation where confirmation is available from other sources. These include: Antigua, Bahamas, Barbados, Belize, Bermuda, Burma, Cape Verde Islands, Costa Rica, Cyprus, Canary Islands, Cayman Islands, Cook Islands, Gibraltar, Honduras, Lebanon, Liberia, Luxembourg, Malta, Marshal Islands, Mauritius, Netherlands Antilles, Panama, St. Vincent, Sri Lanka, Tuvalu, and Vanuatu. If either vessel involved in the event was registered with one of these nations then this case was coded one for *FOC*. (...)

Safety violation indicates that there was evidence of deficiencies serious enough to have grounded the vessel, had the ship been inspected prior to departure by the United States Coast Guard, under its Port State Inspection Program. Reviewing all of the deficiencies found by the USCG inspection program (1998 – 1999 data) produced a list of violations that occur with the greatest prevalence. Primarily, the list includes factors that are considered serious enough to warrant a detention: inadequate or inoperable safety equipment on board the vessel, invalid licenses, lack of crew proficiency with fire-fighting and ship abandonment drills, poor ship maintenance as evidenced by excess oil in the engine room, and et cetera. Each event was carefully researched to see if the primary vessel was described as showing any of these deficiencies. Two variables were created to reflect the presence of substandard conditions. The first simply tallied all of the deficiencies and the second, was a dichotomous variable coded one if there was evidence to suggest that the vessel could have been detained. Because there was much variability among the quantity and quality of information about each case, the ratio level variable (total number of deficiencies) was not used in this analysis.

ii. Defining System Hazard

(...) six variables were combined in an additive fashion to create an index of system hazard: enforcement capacity (*GDP*), exposure to hazard (*voyage length*), high traffic areas (proximity to *harbors* and *busy shipping lanes*), collision with another vessel (*COLB*), and finally, inclement weather (*weather*). An additive function was used because prior research failed to identify the

mathematical function that produces component interaction. In the absence of precedence, the additive model that weighs each factor equally was the most logical starting point. Below, the discussion details the construction for a few key elements of this term.

Regional enforcement capacity was not directly measured. Instead, the gross domestic product per capita in 1995 US dollars (*GDP*) presented an indirect economic measure of the nearest nation's ability to regulate and respond to maritime concerns.¹ Figures were taken from the International Monetary Fund's World Economic Outlook (WEO) Database of April 1999.² The gross domestic product in billions of US dollars was adjusted for each nation so that the figures were in constant 1995 dollars. Data were not available prior to 1970.

Measuring exposure to hazards involved the voyage length (nmi). Voyage length approximates the duration spent within the hazard for that trip. To create voyage distances both the origins and destinations were plotted on a digital map of the world. Then, by referencing shipping lanes, intermediary stops and general voyage descriptions, the most probable route taken by each vessel was plotted. The ArcView© function called "find distances" was used to estimate the route length in nautical miles. For round trips and cruises, this distance figure was doubled.³ The average voyage length per region was used to estimate missing values. In order to combine this factor into the index, quartiles were used to distinguish, minimum (0-25th quartiles), minor (26-50th quartiles), moderate (51-75th quartiles) and major exposure (76-100th quartiles). The minimum category was assigned a value of ".25"; minor exposure was valued at ".50"; moderate exposure was valued at ".75"; and finally, major exposure received a value of "1".

Evidence suggests that system hazard should be most extreme and vessels most vulnerable, when in proximity to high traffic areas. Vulnerability was measured by two factors: whether the event occurred within 1.5 nmi from a port, and whether the event occurred in a high volume shipping lane. Major shipping lanes with a high volume of traffic are listed in Table 12.

[Table 12 about here]

Selection of high traffic water bodies used graphic and statistical information provided in a map of ocean transportation routes located in the New International Atlas (Rand McNally, 1994). To be considered high volume, at least 200 million metric tons of cargo must be carried over the route annually. Additionally, the list

¹ A more appropriate measure would be the amount of funds dedicated to search and rescue operations, Coast Guard activities, and government regulation of the industry. Such figures were not available, on a global basis, for the entire study period (48 years) hence, an alternative economic measure was used.

² The WEO Database of April 1999 is available on the internet at www.imf.org/external/pubs/ft/weo/1999/01/data/index.htm. This database was downloaded on September 21, 1999 at 7:51 pm.

³ Where the cruise route was not specified an estimate for the type of voyage replaced the missing value. For example, 14 day Alaska cruises typically start in Vancouver, Canada; proceed to Juneau, Alaska and then, conclude back in Vancouver.

included the North Sea because of the high volume of passenger vessel traffic that it supports. Both of these indicators of high traffic areas were manually coded in a dichotomous fashion.

Table 12. Straits, Seas, and Areas supporting High Levels of Maritime Traffic.

Straits	Seas	Areas
Turkish Straits	North Sea	Manila Bay
Bosporus	Mediterranean Sea	Inland Sea (Japan)
Dardanelles	Sea of Marmara	Suez Canal
English Channel	South China Sea	Persian Gulf
St. of Dover		Bab el Mandes
Malacca Strait		The Gulf of Adhen
Mactan Channel		
Luzon Strait		
Strait of Gibraltar		

COLB indicates whether the event involved a collision between two or more vessels. This variable was included because research shows that collisions between vessels are generally the product of failure to adhere or understand the rules of the road (Gardiner, 1981). Here the event receives a code of zero if the collision does not involve another vessel.

Finally, events wherein *weather* was a contributing factor were coded in a dichotomous fashion as well. This factor represents the natural hazard presented by the interaction between climate and sea conditions. It is also an indirect measure of production pressure (...). As stated previously, the above variables were added together to form an index that represents system hazard.

Appendix B

Below are excerpts from Bichler-Robertson (2000:118-119) that details how the variable “seriousness” was created. For the purposes of the univariate analysis categories were collapsed—minor and light were collapsed into minor, categories serious and major into serious, and categories disaster and catastrophe were clasped into catastrophe—due to insufficient numbers.

Classification of maritime losses is often computed by tonnage and number of deaths. (...) Following the precedent of Hooke (1997) and other maritime research, event seriousness employed seven levels or categories (See Table 14). Categories were developed from variation in three factors namely, fatalities of passengers or crew, injuries among those on board, and the extent of damage to the vessel.

Table 14. Levels of Seriousness based on Fatalities, Injuries and Financial Loss associated with Damage to the Vessel.

Level of Seriousness	Code	Defining Characteristics
Minor	0	No injuries to passengers or crew, and no damage to the vessel.
Light	1	No injuries. Minor damage to the vessel or other structures.
Moderate	2	Up to 15 injuries with minor/repairable damage to the vessel.
Major	3	No death but with major/TL/TCL* damage to the vessel.
Serious	4	Up to 15 deaths and TL/TCL damage or 15-40 injuries and major damage.
Disaster	5	> 40 injuries/deaths and major damage to the vessel.
Catastrophe	6	>15 deaths and TL/TCL of Vessel or >40 injuries/deaths and major vessel damage.

*** TL symbolizes the total loss of a vessel. This means the vessel sank and was not recovered or was completely destroyed. TCL refers to a total constructive loss, meaning that the cost of the damage exceeds the insured value of the vessel.**

In some situations no injuries were reported; this does not mean that the casualty did not cause human injuries, but that conclusive information was not available. An estimation procedure was developed in order to reduce the number of missing values for this variable. When accurate fatality and vessel fate information were available and the number of injuries missing, one of three adjustment figures were multiplied by the manifest to conservatively estimate the number of likely injuries. For events were 75 to 100 percent of the passengers and crew survived and there was serious damage to the vessel (either TL or TCL), five percent of the manifest was estimated to have sustained injuries. In situations where 50 to 74 percent of the manifest survived and the vessel lost, ten percent of those on board were expected to have suffered injuries. Finally, where zero to 25

percent of the manifest survived and the vessel declared a total loss or total constructive loss, missing values for injuries were replaced with 15 percent of the people involved in the event.

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Endnotes

ⁱ There were a total of 653 events discovered that met the selection criteria, of which 121 were excluded due to insufficient evidence. A detailed bias analysis revealed that the excluded events were to be very serious events occurring in Southeast Asia (for more information see Bichler-Robertson, 2000).

ⁱⁱ The large number of recent events reflects improvements in availability of data and the development of global information networks. Analysis of the characteristics of events over time does not reveal significant differences in the nature, seriousness or circumstances of casualties.

ⁱⁱⁱ The US based cruise industry has been expanding since the early 1980s: the number of cruise ship passengers embarking from American ports has grown between eight and 15 percent each year (GAO, 1993; McDowell, 1991) . To meet the demand, new, megaships are being constructed: twenty-one new cruise vessels were scheduled for launch in 1998 alone (Borcover, 1996).

^{iv} For more information about Port State Inspection programs please refer to Bichler-Robertson, 2000.